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SPEED GOVERNMENT IN WATER-POWER PLANTS.

BY MARK A. REPLOGLE.

No problem in hydrodynamics has created so much interest in the past few years as the government of water-powers. When it had been demonstrated that power could be successfully transmitted to great distances by the use of electric currents, the economist very naturally conceived the idea of harnessing available waterfalls. It was well known that turbine water-wheels could be constructed that would furnish to a dynamo an efficiency of 75 per cent., or more, of the energy represented by the fall or head. The conservative engineer and the investor, however, were much concerned about the

possibilities of regulation or government, and much diversity of opinion has been expressed by thoughtful and earnest engineers regarding it. Specialists have spent much labor in experimenting and developing apparatus to govern power plants. It has been demonstrated that water-power plants can be successfully governed. But the various degrees of regulation, ranging from indifferent speeds up to good engine practice, even with the same apparatus when used in different water-powers, prove that there are some underlying principles that must be adhered to if successful regulation is to be obtained by calculation or intelligent reasoning, and it is for the purpose of discussing some of these principles that this paper has been prepared.

Very little literature can be found that treats on the government of water-powers in a scientific manner, and what is extant shows that the German, Swiss and French engineers had spent much thought and labor on this subject years before the problem became an important one in America. Space forbids any comments on their experiments or practice, except to say that, until within a very few years, they were far in advance of our own hydraulic engineers in this particular part of power-plant construction.

Regarding the *early* work in this line, nothing better can be said than to quote the "Encyclopædia Britannica," which says: "The science of hydrodynamics was cultivated with less success among the ancients than any other branch of mechanical philosophy. If we except a few propositions on the pressure and equilibrium of liquids, hydrodynamics must be regarded as a modern science which owes its existence and improvement to those great men who adorned the seventeenth and eighteenth centuries." During the early part of the nineteenth century rapid advances were made by Europeans in methods of getting power from gravity by the use of the agent water. The interest awakened by the success attained, as well as the necessity of good government in localities where steam power was expensive, no doubt had much to do toward an early development of governing apparatus in the European countries. In America, steam-power has been so

cheap as almost to supersede water-power in some localities, and where steady power was a necessity it was almost invariably furnished by steam engines, water-power being used only where little or no government was required. Hence the American manufacturer was fairly satisfied with a device that would slowly move his wheel gates when too great a change was perceptible in the speed of his plant. Such device was called a governor until the electrical engineer of recent years discovered that his machinery was safer if he ignored entirely the so-called water-wheel governor.

The late successes in long-distance transmission make water-powers more valuable than they have been considered in the past, and the demands for reliable speed regulation are so urgent that there is a decided tendency on the part of engineers and investors to study the proposition more from a scientific point of view, laying bare, if possible, the principles that underlie it. These principles then may be used for foundations from which to reason out a solution of the problem. The doubts concerning the satisfactory government of water-power have often caused capital to be withheld where it otherwise might be earning handsome dividends. It is very apparent that speed government in water-powers should be reduced to an exact science, if possible, and it is hoped that this paper will exert some bearing to that end.

The following preliminary view of the proposition will disclose some of the difficulties that do not appear at first thought: First to be considered is the water. It is an inert material, incompressible, and having inertia, hence momentum when in motion. It contains no power whatever except that generated by gravity in giving it motion. Perhaps no better demonstration of the evil effects of inertia and momentum in governing can be given than the experience at the power plant of the Fresno transmission. (*Plate I.*)

A feeder pipe about 3,800 feet long is used to carry the water from *A*, the outlet of a reservoir on a mountain top, to *D*, the power house on the San Joaquin River. The fall or head in this case is 1,410 feet, and the pipe is amply heavy for all the ordinary strains that come in the manipulation of the

power. Before the plant was ready for actual operation, through some accident, a valve at *D* was opened, allowing a 4-inch stream of water to escape; the pressure gauge, which ordinarily showed 610 pounds to the square inch, dropped to 350. The valve at *D* was almost immediately closed by the attendant when the pressure-gauge pointer ran up to its limit, 1,000 pounds to the square inch. Immediately following this was a great writhing in the pipe line, ending in a report at *C* about 700 feet vertically above the power house. The pressure gauge dropped to about 300, and the flood of water coming down the mountain side indicated that the pipe had burst at *C*.

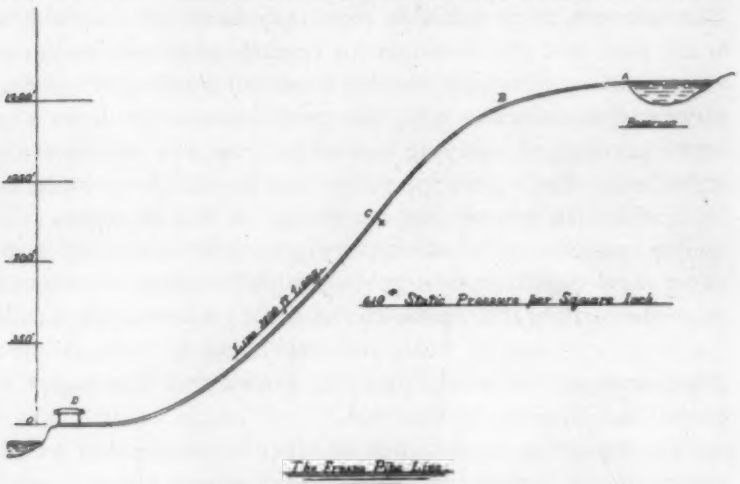

PLATE I.

Further investigation showed that the pipe from *A* to *B* had collapsed or flattened. The logical conclusion is, that when the valve was opened at *D* the portion of the water column from *B* to *D* began moving. That portion of the column from *A* to *B* lying in an almost horizontal plane did not have its inertia overcome quickly enough to follow, hence the column separated at *B*, causing a vacuum from *B* to *C*. When the valve at *D* was closed the water from *D* to *C* came to a standstill, raising the pressure by its momentum to 1,000 pounds per square inch, showing proof that the engineers had calculated correctly. By the time that the valve was closed at *D*

the column *A B* had been acted upon by gravity for some seconds, thereby giving it time to acquire considerable velocity, hence momentum; therefore, when it reached the other column at *C* the concussion burst the pipe, showing at one bold stroke the effect of incompressibility and momentum. The collapse in the pipe from *A* to *B* was due of course to the water emptying faster at *C* than it could enter at *A* (the pipe line here being of much lighter steel).

It can readily be seen that if government in this plant were attempted by changing the flow in the pipe line, as is ordinarily done, it would have been an impossibility if the safety of the installation was a consideration. Hence the governing is done by shifting a stream of water on or off the wheel as the power-demands require.

It might be added incidentally that the stream from a nozzle 1⅜ inches in diameter furnishes about 500 horse-power, also that said stream can very quickly bore a hole through a granite rock or even a steel plate. It requires much care and ingenuity to handle this power plant, but it has been in actual operation for nearly two years, and is an unqualified success.

The inference to be drawn from the above experience is, that these evil effects appear in every power plant in a corresponding ratio to the length of pipes or closed flumes used to carry water to wheels. The injurious effect on government is to *change* momentarily the pressure or head on the wheel when any movement of the wheel gate is made. The effect is always the opposite from that required to keep even speed. Hence there is a limit to the time allowable in the gate movement.

The second factor to be considered is the water-wheel itself. It has a possible range of speed from zero to even faster than the spouting velocity due to the head, and it is unlike a steam engine in many respects. Its periphery must move at a velocity that is a proper ratio to the spouting velocity of the head, in order to gain the highest efficiency of power. The wheel also allows practically the same quantity of water to pass through it at any of its possible speeds. If any difference, it allows more water to pass through it at underspeed than it does at overspeed. So it can be readily seen *that*

an accurate gauging of the water that enters the wheel does not necessarily have anything to do with the speed. The speed of wheel is the result of quantity of water combined with pressure on one hand and load of work on the other. Therefore, any change in one of these three factors causes a change in the speed.

If a wheel at the end of a long-closed pipe containing hundreds of tons of water were running at normal speed, carrying a certain load, its speed would remain constant if no changes were made in the conditions. If, however, the gates were *slowly* opened, its speed would be increased by the greater quantity of water entering it. If, instead of this, a part of the load were dropped off, the speed in like manner would rise. If the gates were *slowly* closed the speed would soon begin to fall. But if the gates were *rapidly* closed the momentum of this column would cause a much greater pressure at the wheel-gate openings, and for an instant cause practically the same amount of water to enter the wheel at higher velocity. This amount of water having higher velocity will contain more energy or power for the time being, and of course will impart more to the wheel, increasing its speed slightly for a short time instead of immediately decreasing it, as would seem natural. This tendency for an increase in speed, added to the increase already caused by a part of the load being dropped, will make it necessary for a greater amount of work to be done by a governor than would be proper after the momentum effects in the pipe had subsided. It can also clearly be seen that, if the gates are opened again *quickly*, the velocity of the water entering the wheel will be decreased until the whole column acquires an increased motion; hence, the power applied will be diminished for a time instead of increased. These momentary and opposite effects make water government a harder problem to solve than the government of steam.

Third, water-wheel gates, as compared with steam valves, are heavy and unwieldly. They must also be moved through water, which is much denser than steam, hence cannot be moved with the same facility. They require much more power for *their movement.* Sometimes the designer of a water-power

plant does not place importance enough on the government of the wheels to make substantial gate rigging. The gate shafts may be too light, showing torsion when operating, or there may be a train of cog gears that allows much lost motion. The gates may be so designed that the water pressure gives them an unbalanced condition, requiring much pressure to be neutralized before it is possible to move them in a reliable manner. Turbine wheel gates built in this country often weigh several thousand pounds each, and sometimes must be moved several feet through water in being opened. Often it is necessary to add weight equal to their own weight as a counter-balance. The power required to overcome the inertia of and move this great mass often reaches many thousands of foot pounds. It can readily be seen that to govern such gates with precision and accuracy requires a combination of both delicate and powerful machinery. Also, when it is considered that it is possible to make the full change of an electric load in the fraction of a second and impossible for gravity to meet the power-demands short of a number of seconds, it is plain that to govern a water-power plant successfully is a matter of more moment than would seem at long range. It must also be borne in mind that the change of load must *occur*, and the speed must be *impaired* before it is possible for a governor to operate at all.

The fourth element to be considered is gravity, the source of all energy or power that can be had from water. Its effect can be considered as a constant in reasoning about power-getting. Of course, it is variable within certain limits. A square inch of opening at the bottom of a vertical column of water will allow gravity in a given time to generate a number of foot pounds of power, and in direct ratio to its height. This power is absorbed in giving velocity to a stream of water an inch square and spouting a number of feet per second. *Gravity has established an equilibrium in giving this velocity to the water.* If the opening were increased the power generated would increase in like ratio. It is the duty of the turbine wheel to reduce the velocity of this water as nearly as possible to zero without changing its own speed. In so doing the power is

transferred to the wheel shaft, where it can be carried to other points. With the exception of the small amount of power that is required to give a slow, downward movement to this vertical column of water, it can be said that the full effect of gravity is represented at the gate opening. Also, as soon as the opening is increased or diminished, there is practically the same increase or diminution in the amount of power represented by the volume and velocity of the water.

Again, if this column of water was extended in a horizontal direction from the top of the vertical column and the whole encased in a closed pipe or trunk, it can readily be seen that, when gravity operates on one square inch at the foot of the vertical column, it must put in motion the horizontal mass of water at the same time that it does the vertical mass. It is plain then that, while gravity has begun active operation as soon as the opening is made, its full effects will not be represented at the opening or wheel until the whole mass has been supplied with enough kinetic energy to give the necessary motion for the full spouting velocity at the gate opening. It is apparent that, while gravity is limited in the amount of power it can supply in a given time, it can be, and often is, further limited in its time of supplying power for governing purposes by the use of long pipes.

Considering the facts, that a change of load must be made before a governor can begin operating, that it requires time for a governor to perform its operation, that torsional and lost-motion effects are found in all gate riggings, that gravity must have time to do its work and may further be obstructed by injudicious flume construction, and that the wheel is limited to a certain opening and need not necessarily run in the ratio of the amount of water passing through it, it follows that absolute speed cannot be obtained in water-powers under heavy changes in load, as a change in load must necessarily change the speed before it is possible for gravity to furnish an increase in the supply of power. If there were no other factors government would be an impossibility, as a change of 50 per cent. in load would instantly cause a change of 50 per cent. in speed. But there *are* other factors, and, be it said to the credit of the

great engineers who designed America's greatest water-power plant, these other factors were clearly understood, intelligently calculated and incorporated into its construction. They are visibly stamped in every part of its make-up. (*Plate II.*) The first notable element is the size of the power units, 5,000 horse-power each. The second is the capacity of each unit for a storage of kinetic energy. It is absolutely necessary to have an accumulation of energy in reserve to tide over sudden fluctua-

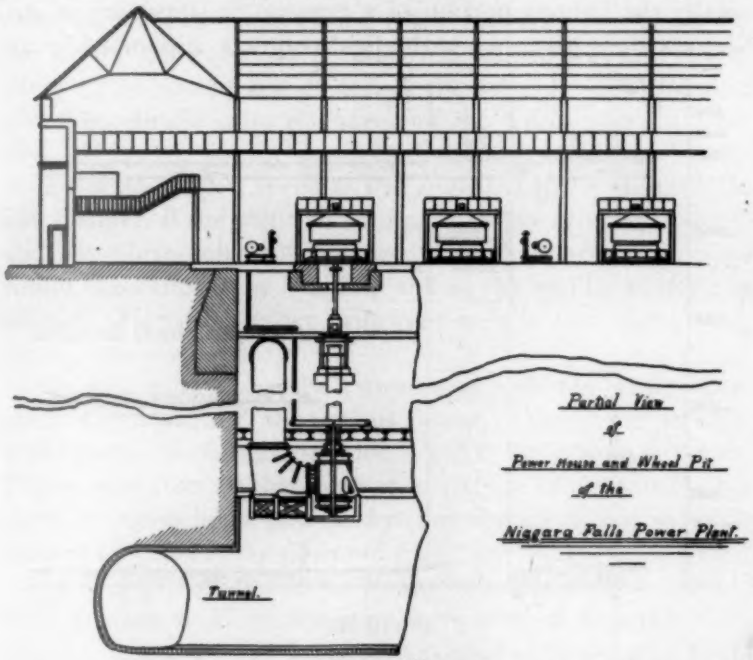

PLATE II.

tions in load until gravity can make proper compensation. The designers of the great Niagara plant first determined the degree of government necessary or desirable, and from this as a basis the plant was constructed. The results show that the speed government is well within the limits for which the units of power were designed. It is evident that there is a great accumulation of energy in reserve when an instantaneous change in load of 1,000 horse-power causes only 2 per cent. variation in speed, especially when the conditions are such

that it requires about three seconds of time for gravity to increase the power-supply to this amount.

There are several methods by which a reserve storage capacity can be maintained, but the one used at Niagara seems to be the simplest and most reliable. It certainly is the cheapest, being also purely mechanical. Reference is now being made to the balance-wheel or momentum effects of the revolving parts. It will be remembered that the armature, which is usually the lightest portion of a dynamo, is stationary in the Niagara Falls plant, while the field magnets, supported by an

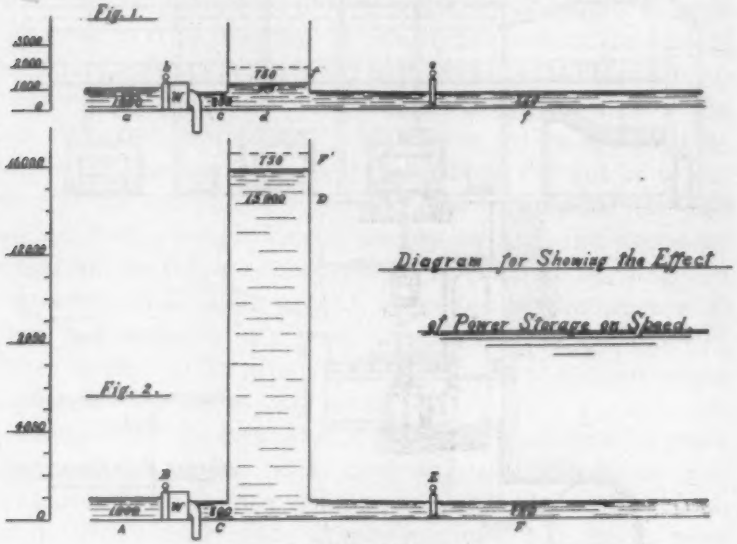

PLATE III.

immense steel band, are the moving parts. It is also noticeable that the great shafts reaching downward to the turbines are of large diameter, being great tubes. This is for the purpose of giving high velocity to as much of the material as possible. A certain capacity for stored energy was necessary for good government, and it is safe to say that if this could not have been reached with the present weights and velocities of parts, more would have been added in the form of actual balance wheels.

Plate III will serve to make clear the effects of power-storage in the government of a water-power unit.

In *Fig. 1* let *a* represent the power supply, *b* the water-wheel gate, *w* the wheel, *c* the turbine power, *d* the power storage, *e* the means of changing the load, and *f* the dynamos' power. It will be noticed that full 750 horse-power can be dropped off instantly by closing means *e*. The governor must operate at *b*, and it is safe to say that it cannot be in active operation before one second has elapsed. Note the condition at the end of the first second after the 750 horse-power was dropped. When *e* was closed there was only one outlet for the power generated at *w*, and that was to increase stored energy *d* to dotted line *f'* during the second. This increase will theoretically raise the speed of the whole plant 100 per cent. If it were not for some other principles that step in, this would be the actual speed at the end of the first second. In like manner, if the plant was running empty at normal speed, and 750 horse-power of load were added instantly, the plant would theoretically be standing still at the middle of the first second. Here also other principles step in and change this result somewhat.

In *Fig. 2* let *A* be the power-supply, *B* the water-wheel gate, *W* the wheel, *C* the turbine power, *D* the power storage, *E* the means of changing the load, and *F* the dynamos' power. Please note that all the conditions are the same, except that there is 15,000 horse-power of stored energy in *Fig. 2*, while there is only 375 horse-power in *Fig. 1*.

If *E* is closed, 750 horse-power will be dropped off, and finds a place at *F'*, increasing the volume of *D* 5 per cent., hence will theoretically increase the speed of power unit about 2½ per cent. by the end of the first second. This is also lessened somewhat by the same principles that affect *Fig. 1*.

It can readily be seen that here is a means of preventing extreme changes in speed until gravity can perform its part of the work. Note the conditions in *Fig. 2* if running at speed and a load of 750 horse-power were added. If the load were suddenly added it must be carried from the reserve power at *D*, using 5 per cent. of it during the first second, hence reducing the speed about 2½ per cent. theoretically. It can readily be seen that the speed will continue to drop until balanced

by new power generated at *W* after the governor has opened gate *B*. It can now easily be seen that *D* in any power plant can be increased until full change in load can be made with very narrow fluctuations in speed. In other words, every foot-pound of power or change in load can be intelligently provided for in the construction of a power plant, and variations in speed can be calculated for any change in load if the other conditions are known.

TABLE I.

POWER STORAGE OF SOME WELL-KNOWN PLANTS.

Name.	Units of H. P.	Power Storage Capacity in H. P. for 1 sec.	Ratio of Power to P. S.
Niagara Falls P. Co.	5,000	50,000	1 to 10
Sacramento L. & P. Co.	1,000	8,000	1 to 8
San Joaquin E. Co.	450	9,000	1 to 20
Portland G. E. Co.	600	3,000	1 to 5
Niagara Falls Paper Co.	1,200	400	1 to 1/3

Table I will serve to give an idea how the power units of plants differ in the ratio of their power to their power-storage. It is safe to say that if the other conditions were equal the possible government in their speeds would show equally as great a difference. Space forbids any further comment, except that each plant is desirous of good government.

TABLE II.

APPROXIMATE LENGTH OF FEED PIPES IN EXISTING PLANTS.

Place.	Head.	Pipe.	
Ithaca	94′	600′	Ithaca Pipe
Great Falls	40′	400′	contains 737,500
Spokane	60′	600′	$MV^2 = 11{,}800{,}000$
Brantford	30′	210′	$= 338$ H. P.
Fresno	1410′	3800′	of kinetic energy in
Niagara Falls	145′	200′	in pipe.

Table II is intended to show the horizontal lengths of feeder pipes of some of the existing electric water-power plants.

It is unnecessary to go into the details of the calculations, but the purpose is to show the possible effects of momentum if the water-flow was stopped as quickly as an electric load is sometimes dropped. Taking the first in the list, that of the Ithaca Street Railway Company, it is found that the pipe holds 737,500 pounds of water. Assuming that this column

has a maximum velocity of 4 feet per second at full load, there will be a pressure of 11,800,000 pounds, or over 4,000 pounds per square inch at the water-wheel end of the pipe if the gates were closed as quickly as the load is dropped off. Since the static pressure is less than 50 pounds per square inch, and only a reasonable factor of safety provided, it is evident that a serious wreck would be the result of such a quick closing of gates. Yet such is necessary, theoretically, if even speed is desired.

It is also noticed that there is in this pipe before closing the gates 338 horse-power of kinetic energy for 1 second. Some disposition must be made of this energy, as it is necessary that the column of water be at rest when the wheel gates are closed. The only available disposition of it is to allow it to join the power set free when the load is dropped off, increasing its effect a like amount until the wheel gates can be safely closed.

It can now readily be seen that it is not only necessary to provide power-storage capacity enough in a power unit for the changes of load, but also an additional capacity for that contained in the pipes or flumes. This extra power must be provided on opening the gates before the wheel will furnish new power, and must be disposed of before the wheel will stop furnishing power when the gates are being closed. In other words, if the power unit in question is 900 horse-power, and calculations were being made to provide power storage so as to allow a full change of load to be made, keeping the speed inside of a given per cent., the calculations must be based on 900 horse-power plus 338 horse-power or 1,238 horse-power change at the whole gates. This makes it clear that closed pipes should be avoided as much as possible, if the government is to be done by changing the flow of the water. If it is desired to govern by deflecting the stream in some manner, the only detrimental effect of the long pipe is the power lost or gained by the varying friction in changes of load.

Plate IV is intended to show the conditions of speed on a 2,100 horse-power plant when 1,000 horse-power of load is instantly added. The kinetic energy in the pipe at full load is 1,000 horse-power for one second. The power storage of the

plant is 50,000 horse-power for one second. Assuming that the speed of plant is at normal or zero line until it reaches vertical time line marked zero, where 1,000 horse-power of load is instantly thrown on. This being 2 per cent. of the power storage, would cause a drop in speed of about 1 per cent. during the first second after the change. If no power were added, the speed would drop a trifle more than 1 per cent. during the second second, and continue to drop at an increasing ratio as the velocity of the revolving parts decreased. The curve indicated by the ciphers will show how the speed will drop during the following seconds if no new power were added to the wheel. Since it will require seven seconds to move the gates, the ratio of additional power-supply will be 300 horse-power per second, with a maximum action of the governor. Since

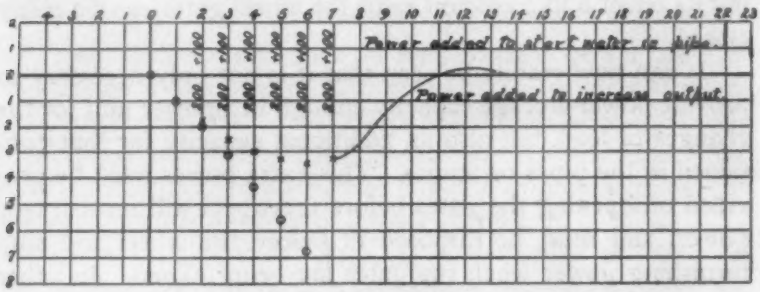

PLATE IV.

the increase in load is 1,000 horse-power, and 500 horse-power additional of kinetic energy must appear in the pipe, it will take the governor five seconds to add power enough to stop the speed dropping. Also, since the kinetic energy must be added to the flume in the same ratio that the new power is available, it is plain that only two-thirds of the 300 horse-power added each second is available as additional power while the velocity of water in the pipe is being increased. Hence only 200 horse-power is added as increased output for each of the following five seconds. This curve is indicated by the crosses at the ends of the several seconds. It can be readily understood that fully one second will elapse before any power-supply can affect the speed of plant. It can also readily be seen that the power storage must carry the 1,000 horse-

power new load for first second. While 200 horse-power has been added during the second second, it has performed an average of 100 horse-power work during this time. The power storage then has carried 900 horse-power of the new load during the second second. Since the full 200 horse-power is being added each second, the power storage is being gradually relieved of its drain and the speed stops dropping accordingly. A calculation at the end of each second shows exactly where the speed is at such time. Space will not admit the figures here, but the curve outlined by the crosses is approximately correct.

It is now evident that a formula can be deduced that can be relied upon in the government of water-powers. It will be somewhat complex on account of the many factors that must necessarily enter into it. Many of these factors will necessarily be fixed by the conditions that attend the plant construction. The size of the power unit will always be decided upon first. Next will be the maximum change in load, with the greatest variation in speed permissible. The time of change in power-supply is dependent upon the action of gravity and the safety of the plant. When the time required to supply power for the change of load has been learned, it is an easy matter to calculate the amount of stored energy or power storage that must exist in the plant in order to keep the variation of speed within the required limits. It will not be necessary to explain the fact that the speed will vary a fraction less in dropping off a load than it will in adding it.

In reducing the formula to its simplest form it will be necessary to combine or add together quantities that are of the same denominations, as follows: The time necessary to add power to overcome the increased friction in penstock, plus the time necessary to add power to overcome the inertia of the increased flow, plus the time necessary to add power for the new load, may be represented by T. The power necessary to equalize the increased friction, plus the power necessary to overcome the inertia in giving increased velocity to the supply, plus the power necessary to carry the increased load at speed, may be represented by L. The variation allowable in

speed in terms that are a fractional part of normal speed may be represented by F, and the power storage may be represented by S. Since the power storage must carry the new load for one-half of T, and since the speed of plant varies in one-half of the ratio that the stored energy is given out or absorbed, it is evident that the formula must read:

$$\frac{\frac{T\,L}{2}}{2\,F} = S$$

Further reduction makes it read:

$$\frac{T\,L}{4\,F} = S$$

The following example will make its use understood:*

In the formula let T represent four seconds, L 1,500 horse-power, and F 3 per cent., or $\frac{3}{100}$ variation of speed allowable. In making substitution and reducing, the stored energy or power storage in the power unit must be 50,000 horse-power. This is the amount necessary if 1,500 horse-power is to be added, and it requires four seconds to get the proper effect from the power-supply, providing the variation in speed must not be over 3 per cent. from normal.

Before closing it will be necessary to make a few suggestions concerning governors. A properly-constructed governor must open the water-wheel gates as fast as gravity can follow up with water, no faster. It must close the gates slow enough to insure safety to the penstocks, no faster. It must be capable of stopping the gates at any degree of opening. It must be endowed with the relay principle, adjusted to co-

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* In the formula $\frac{T\,L}{4\,F} = S$

Let $T = 4$ seconds

$L = 1{,}500$ H. P.

$F = 3$ per cent. or $\frac{3}{100}$ variation in speed.

By substitution we have

$$\frac{4}{4} \times \frac{1500}{\frac{3}{100}} = \frac{6000}{\frac{1}{100}}$$

$= 50{,}000$ H. P. $= S$.

operate properly with the power storage. It must *not* be a separate and independent feature of the power plant, but must be made a part of the plant in an intelligent manner, and at best it is only one of the factors in the government of a water-power plant. It must be remembered that all the governor can do is to open or close the gates as the variations in speed require, and no water-wheel can be governed successfully by varying the gate-openings unless the same principles are adhered to that make government in steam engines a success.

The *relay* principle allows the governed motor to run at a slower speed when loaded than when running empty. This is for the purpose of using systematically the stored energy of the revolving parts of the power unit. Recently a new feature,

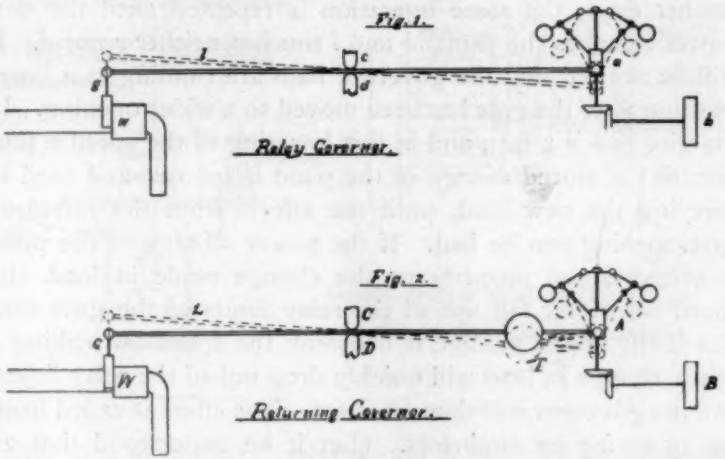

PLATE V.

generally known as the *returning* principle, has been added to some of the best-known governors. Both the *relay* and *returning* features will be shown in *Plate V*.

It is well understood that water-wheel gates are too ponderous to be moved directly by the centrifugal effect of governor pendulums. It is necessary to allow the speed governor to trip some heavier mechanical apparatus which moves the heavy gates. In some governors the pendulums throw into action an auxiliary power that in turn trips the apparatus that moves the gates. In *Fig. 1*, *a* is a speedy governor, *b* its pulley

that receives motive power from the water-wheel shaft, *c* is a trip to cause the heavy apparatus to close the gate, *d* is a trip to cause the mechanism to open the gate, *w* is the wheel, *g* is the wheel-gate, and *l* is a connection between gate and speed governor. (For the sake of convenience in the illustration *l* is a straight lever.) When the lever is so held by the governor balls that it touches neither *c* nor *d*, the gates do not move. If a change in load causes the speed to drop, the governor balls will allow *l* to touch *d*, and immediately cause the power mechanism to begin to open the gate. The gate in opening will raise *l* off of *d*, as is shown in dotted lines, causing the gate-moving apparatus to drop out of action. If this operation did not add new power enough to prevent the speed from a further drop, the same operation is repeated until the new power balances the demand and *l* touches neither *c* nor *d*. It will be noticed that the governor balls are running at a lower position after the gate has been moved to a wider opening. In practice this is a fact, and in this lowering of the speed a portion of the stored energy of the plant is fed out and used in carrying the new load, until the effects from the increased gate-opening can be had. If the power storage of the plant is proportioned properly to the change made in load, the speed can never fall out of the relay limits of the governor. But if the power storage is deficient, the speed on making a heavy change in load will quickly drop out of the relay limits, and the governor will then be at sea. The effect is called *hunting* or *racing* by engineers. (Let it be understood that an increase in speed will cause *l* to touch *c*, and close the gates in a similar manner.

Fig. 2 is similar to *Fig. 1*, with the exception that *L* is flexible or jointed at *E*. In a change of load *L* operates as a stiff lever, but after the equilibrium has been temporarily restored the lever *L* slowly begins to bend at *E*, allowing *A* to return to its original position. This bending or returning will cause *L* to touch *D* and add a little more water, until *A* has found its original position or speed, as is shown by dotted lines. It will be noticed that the power storage in *Fig. 2* is made use of in adding new load, by lowering the speed in the same man-

ner as in *Fig. 1.* But this defect is corrected later by the *returning* principle. The effect of the returning principle is to return the speed always to normal, leaving it identical with the speed at no load, a condition not ordinarily found in speed government where the relay governor is used.

Let it be understood that all steam engines that are successfully governed are controlled by the use of a relay governor, although it is not apparent to the casual observer. Some of our best steam engines use the returning principle in connection with their governing, although no reference is

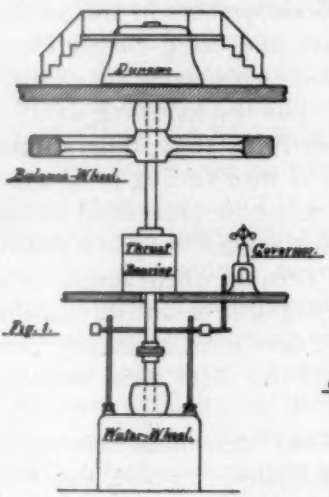

Fig. 1.

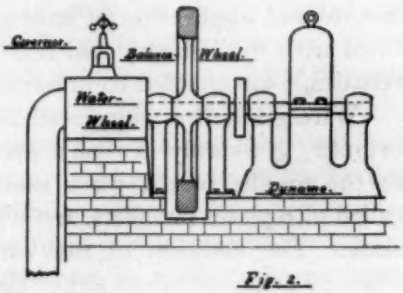

Fig. 2.

General Design of Plant Constructions that are Favorable to Government.

PLATE VI.

made to it in ordinary conversation concerning steam-engine government.

The science of water-power government has not yet reached so great a degree of perfection as the government of steam power, yet the underlying principles are being carefully studied by our engineers, and the time is not far distant when our water-powers will all be constructed and governed as reliably and successfully as our steam plants are, but that time will not come until the same principles are recognized in the former as in the latter. (*Plate VI.*)

Mining and Metallurgical Section.

[*Stated Meeting, October 13, 1897.*]

Mr. Benjamin Smith Lyman, President, in the chair.

RECENT DEVELOPMENTS IN THE MANUFACTURE AND APPLICATIONS OF WIRE-GLASS.

By Francis Schumann.

Having been requested to bring before you any facts and information bearing upon recent developments in the manufacture and application of wire-glass, and being closely identified with the industry and occupied in observing its characteristics, I am enabled to present to you the following data:

Wire-glass, first suggested as early as 1854, differs from ordinary glass only in that a sheet of wire netting is inserted in the middle of the glass sheet while in process of being rolled into plates or sheets, and while the glass is yet in a plastic state. The addition of the wire netting when successfully inserted does not affect either the strength or ductility of the glass to any appreciable extent, but does most effectively prevent disintegration or separation of the sheet after fracture, whether from impact or heat.

It is now and for several years has been manufactured to a considerable extent in the United States, England, and Belgium, and to a less extent in Germany and France. Its principal uses are for skylights, windows and partitions. It is also extensively used as a substitute for iron fire-proof shutters, because it admits light and greatly excels in its fire-resisting qualities.

Wire-glass is made in sheets one-quarter inch thick, and of any size and shape, the maximum size of sheets being 30 inches wide by 120 inches long.

Its fire-proof qualities are extraordinary but will readily be explained if the non-conducting power of glass be considered; thus, sheets of glass set in wooden frames covered with some non-combustible material, such as asbestos cloth or ordinary tin, remained in position and prevented the passage of flames

or hot gases, although subject to a heat on one side sufficiently great to fuse the surface of red brick. The first action of the heat was to expand and bulge the glass, and also to cause cracks. As the heat intensified, the exposed side of the glass partly fused or became plastic, but never beyond a certain degree, no doubt due to the dissipation of heat from the opposite side, which was exposed to the ambient normal air, and which prevented the temperature from reaching a point that would completely melt the glass.

The wire netting, woven of No. 22 B W G wire, having hexagonal meshes about 1 inch across, is not affected by the atmospheric moisture or other corrosive agents, except to a slight degree at the edges of the glass where the ends of the wire are exposed, the imbedding of the wire within the glass proving an absolute protection.

The resistance of wire-glass to breaking does not vary from that of glass of the same thickness without the netting, because the netting lies within the neutral axis of the sheet when considered as a beam subject to a transverse load, nor is the ductility affected, provided care be taken to attain homogeneity when inserting the netting, and also in applying the proper treatment in annealing. This operation causes the greatest difficulty, in that it depends on the application of a certain temperature at a certain stage, and, because of the well-known lack of measuring appliances or instruments, the hitting of the right conditions is largely dependent upon a personal equation. Hence it is that the breakage in one order will be practically *nil*, while in another it may reach an appreciable percentage, although both lots have been made by the same persons with the same methods and with the same care.

Defective annealing causes initial stresses in the sheet of glass, which, unfortunately, do not manifest themselves, no matter how carefully the glass may be examined, until after the glass is set in position and exposed to the elements, notwithstanding the strains it was subjected to when cutting to size or concussions during transportation or handling previous to being placed in position in a skylight. Acquired experience and knowledge are of course lessening these difficulties and gradually removing them.

It has been asserted that failure of wire-glass would finally result by reason of the difference of expansion between the glass and the iron or steel composing the imbedded wire netting. That such is not the case is readily proven. The rate of expansion (or contraction) of iron or steel is about one-third greater than that of glass. This very fact makes wire-glass a possibility, and for the following reasons: The wire netting, when being inserted into the hot and plastic glass, because of its power of rapidly conducting heat, quickly attains the temperature of the glass, and, in consequence, its maximum degree of expansion, the volume of wire being inappreciable compared to that of the glass. The glass being still plastic clings to the expanded wire, but, as cooling proceeds and contraction ensues, it gradually shrinks from the glass, leaving, when entirely cooled, an annular space between it and the glass, and hence no possible strain can come upon the glass from any future variations of temperature which may arise in service.

As to the effect from variations longitudinally, it will be found that the strength of the glass in sheets one-quarter inch thick is so greatly in excess of the ultimate tensile resistance of the wire as to cause it to tear without the slightest effect upon the glass, were it possible to bring the ultimate stress upon the wire. That the wire in the glass is under tension is of course a consequence, and a most desirable result, as experience has shown, in that it tends to closely unite the glass when cracked, and thus prevents leakage from rain; this trait has often been observed and noted, and has been a reason for the retention of sheets in skylights which otherwise would have been removed.

As to the passage of light, recent tests have shown that ribbed wire-glass diffuses more light throughout a building than ordinary glass, the greater efficiency being of course due to the effect of the ribbing.

Wire-glass can be bent or curved into any form. The operation, however, is expensive, requiring special forms or moulds, and its use is consequently avoided as much as possible.

In wire-glass the architect and engineer has an article of undoubted value in the light of modern requirements. A

medium for enclosing space, fire-proof and water-proof, transmitting light, not liable to disintegration by corrosion or combustion, and difficult of penetration, which still maintains its utility, no matter how much it is subdivided by cracks, as it will neither leak nor fall apart and injure those below when used in skylights.

I have here a sample of wire-glass, 1 foot square, cut from a large sheet. The piece was reheated to almost fusion (about 1,200° Fahrenheit), then suddenly immersed to half its width in cold water. You will notice that the piece is yet intact and complete, suitable for any purpose for which it was originally intended.

Here, again, is another sample, showing the mode of decoration when used for partitions or screens; while this third sample is a piece of so-called "rough-ribbed wire-glass," much used for skylights and windows, the ribbing greatly adding to the diffusion of light.

Within the past year the principal manufacturers in the United States, England and Belgium have greatly enlarged their plants for its manufacture, and are making such rapid strides in perfecting the methods of manufacture that it will not be long before wire-glass will be generally accepted as an established commercial product, its process of evolution being analogous to that of steel.

In conclusion, I will exhibit several lantern slides illustrating the action of heat upon the glass, as also a view of a skylight roof, from below, of a large structure in this country, which will permit of a comparison of wire-glass with ordinary skylight-glass.

Figs. 1 to *8* illustrate a test of the fire-resisting qualities of wire-glass, made under the supervision of Secretary Chas. A. Hexamer and Inspector Wm. McDevitt, of the Philadelphia Fire Underwriters' Association, on April the 30th, 1896.*

*The brick test-house referred to in accompanying series of views, was built of 9-inch walls, measuring 3′ x 4′ x 9′, interiorly. Iron grate-bars were placed about 2 inches above the ground level, immediately above the cross-shaped openings arranged to supply air for combustion. The top of the test-house was roofed with a skylight, one side with ¼-inch wire-glass, and the other with ¼-inch rough-rolled skylight glass of the ordinary kind. The

Fig. 1 shows the test-house immediately after lighting the fire and closing the door.

Fig. 2 is a view taken two minutes after lighting the fire. The smoke had blackened the glass of the door and cracked the glass in the window. The half of skylight glazed with ¼-inch wire-glass is on the same side as the window, and shows in this picture.

Fig. 3 is a view taken three minutes after starting fire. The heat is sufficient to warp the wire-glass. The plain glass on the other side of the skylight had just commenced to break and fall.

Fig. 4 shows the condition of things fifteen minutes after starting fire. There is evidence of considerable increase in the intensity of the heat, and evident charring of the wood in the frame and door incased in tin.

Fig. 5.—Fire twenty-five minutes under way. Wire-glass in door and window at a red heat, sufficient to cause the glass to buckle. This buckling was due largely to portions of the firewood pressing against it while in this plastic condition.

Fig. 6.—Fire thirty-five minutes under way. This view shows the side of skylights, glazed with ordinary glass, which had fallen in five minutes after the fire had started. The portions of glass still remaining were protected from direct heat by the thickness of the brick walls immediately underneath, which also prevented them from falling.

Fig. 7 is a view taken after water had been thrown on the skylight while the fire was at its greatest intensity. The walls had cracked, and the plain glass was partly melted, as is seen in the opening at the opposite side of the building. The wire-glass in the window below, owing to the absence of clips, had curved outward at the top. The door was still intact and in position.

Fig. 8 is a view taken after the fire had been extinguished and water had been thrown on the glass with a hose. All of the wire-glass was intact. The panel of the door is seen with the tin covering ripped off, showing the charred condition of the wood inside, but which still retained its form.

Fig. 9 is a photograph of the ruins of two factory buildings at Newark, N. J. One was a five-story and the other a one-story building, separated by an alley 4 feet 8 inches wide. The one-story building contained eight windows, furnished with wire-glass, set in angle-iron frames, in place of iron shutters. The view shows one of these windows after the fire, which caused the fall of the smokestacks of the large building and the destruction of all of the small building; a portion left standing containing the window.

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frame of skylight and the sash-bars were of wood covered with tin, both being glazed with wire-glass held in place by iron clips. A window of ¼-inch thick wire-glass, with iron frame, was set in one side of the house, and the wooden door, with an upper panel of ¼-inch wire-glass, was tin-lined. The tin covering the woodwork has lock seams.

A quarter of a cord of wood, thoroughly saturated with oil and mixed with resin, was placed on the grate-bars ready for lighting.

FIG. 1.—Test-house at starting fire.

FIG. 2.—Two minutes after lighting fire.

FIG. 3.—After three minutes.

FIG. 4.—After fifteen minutes.

FIG. 5.—After twenty-five minutes.

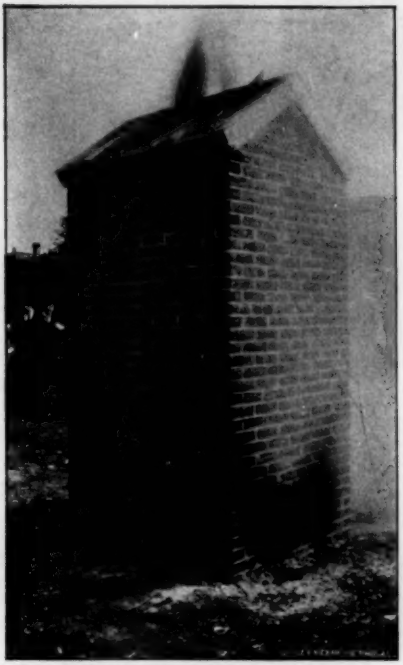


FIG. 6.—After thirty-five minutes.

FIG. 7.—After water had been thrown on skylight. Fire at greatest intensity.

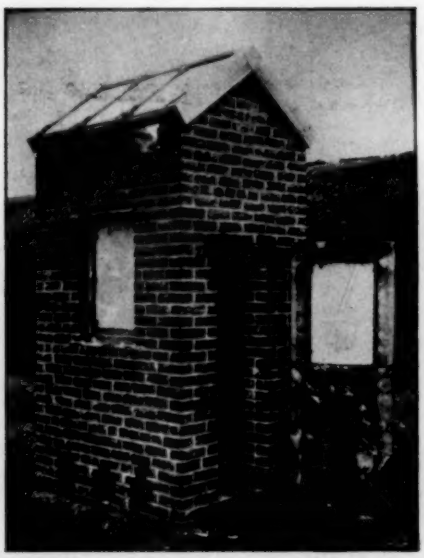


FIG. 8.—Test-house at close of experiment.

OF WIRE-GLASS.—[HEXAMER AND McDEVITT.]

Fig. 10 is an interior view, looking up towards the roof, of a large train shed of a railroad station in one of the large cities of this country. The photograph was taken a few days after a severe March snow storm.

The upper part of the roof was glazed with ordinary skylight-glass, while the lower portion was wire-glass. How the

Fig. 9—Wire-glass window in building of Newark Stamping Company, after fire.

storm affected the ordinary glass will be noticed by the number of broken sheets. The opacity of this part of the section of the skylight is caused by the soot clinging to the glass, the safety wire netting stretched beneath interfering with the proper cleaning of the glass.

While many of the wire-glass sheets were cracked by the

storm, none of them were displaced, and they remain in place to this day. Attention is also called to the bright appearance of the wire-glass section, which denotes its clean condition. This

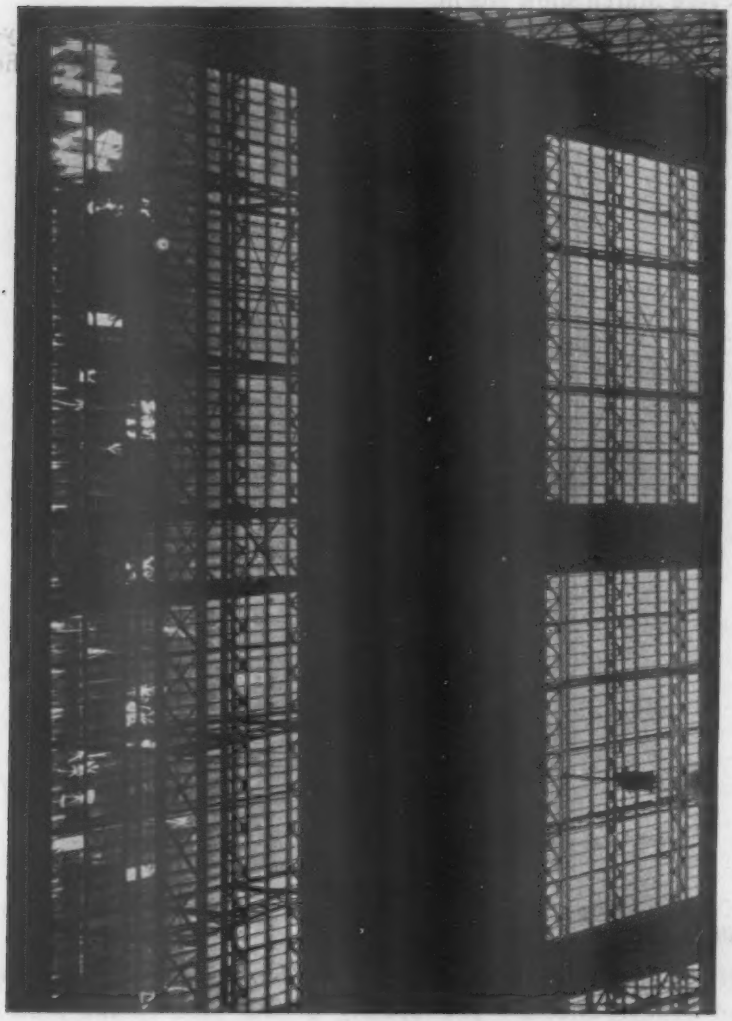


Fig. 10—View of skylight in train-shed, Pennsylvania Railroad, Broad Street Station, Philadelphia, after snow storm, March 16, 1895. Upper section, ordinary skylight glass. Lower section, wire-glass.

is due to the fact that it requires no protecting shield of wire below, which is necessary with ordinary roof lights, and hence interposes no difficulty in cleaning.

THE FRANKLIN INSTITUTE.

Stated meetings, September 15 and October 20, 1897.

MR. JOHN BIRKINBINE, President, in the chair.

THE SMOKE NUISANCE AND ITS REGULATION, WITH ESPECIAL REFERENCE TO THE CONDITION PREVAILING IN PHILADELPHIA—IMPROVED FURNACES AND MECHANICAL STOKERS.

(*Concluded from vol. cxlv, p. 24.*)

THE BLACK DIAMOND SMOKELESS FURNACE.*

THE SECRETARY:—The accompanying illustrations show the design and construction of a smokeless furnace containing all the necessary elements for smokeless combustion and high economy. The simplicity of construction is shown in several illustrations, where it will be seen that the practical operation of the furnace for high efficiency and smokeless combustion is comprised in the method of providing highly-heated surfaces of ample dimensions to maintain the requisite temperature for complete combustion and the provision that it is made for the introduction of a suitable quantity of air to supply such combustion at the proper time and only so long as required.

The bridge wall in this furnace is made to conform to the shape of the boiler for a portion of its height, leaving sufficient space between bridge wall and boiler for passage of the gases, while the main portion of the gases and products of combustion find free outlet through several arched openings in the lower portion of the wall.

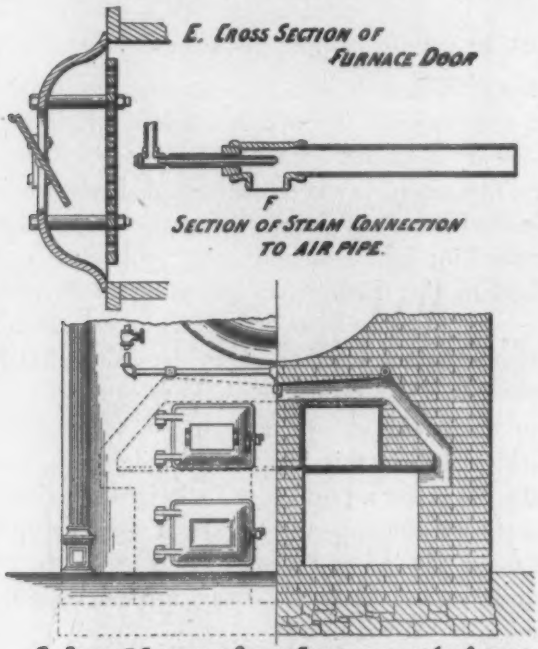
An essential feature is placing the arched portion of the bridge wall back some distance from the grates, to provide an opportunity for the proper mingling of the air and gases and permitting time for combustion to take place before they pass the bridge wall. This is an important feature, for, in ordinary furnaces, sufficient time is not given for the mingling of air and gases before passing the bridge wall, where they come in contact with the cooler boiler-plate, thereby having their temperature reduced below the combining point, so that air

* Manufactured by Bowe & Co., Chicago.

after snow storm, March 16, 1895. Upper section, ordinary skylight glass. Lower section, wire-glass.

and gases mixed, but uncombined, pass off unconsumed, carrying away a large number of heat units that might be utilized by proper arrangement of furnace, such as is here provided.

The temperature required for the complete combustion of the gases of coal with air is known to be 800° and upwards, while the temperature of boiler at the highest steam pressure is less than one-half the ignition point of coal and less than


E. Cross Section of Furnace Door
F
Section of Steam Connection to Air Pipe.
D. Detail & Section of Boiler Front showing Air Passage

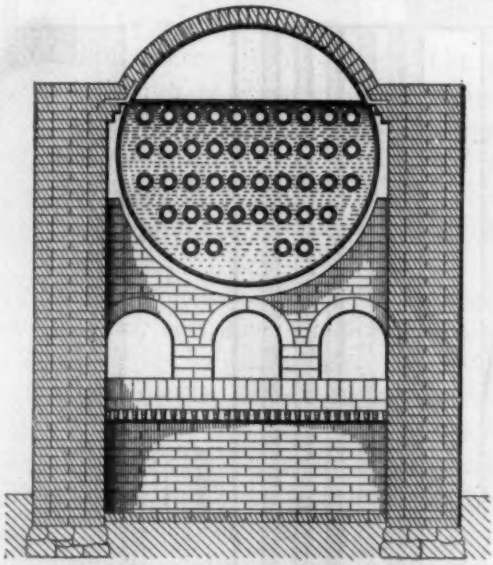
Black Diamond smokeless furnace.

one-third the temperature of complete combustion, so that in furnaces as ordinarily constructed a large amount of heat-making matter is wasted. In the method adopted in this furnace the products of combustion are compelled to pass through the brick flues in the bridge wall, which are always at red heat, a temperature sufficiently high to provide for complete combustion. This temperature being secured, the gases combine with the development of a greater heat and provide

a temperature at which soot, as such, cannot exist, consequently cannot be produced.

The attention necessary with this combination is so slight as to give no inconvenience to the fireman, as the results are obtained automatically after the apparatus is once adjusted to the kind of fuel used and the amount burned. Any change in kind or amount of fuel necessitates but slight and easily-made adjustment of the automatic device.

That part back of the bridge wall, commonly called the

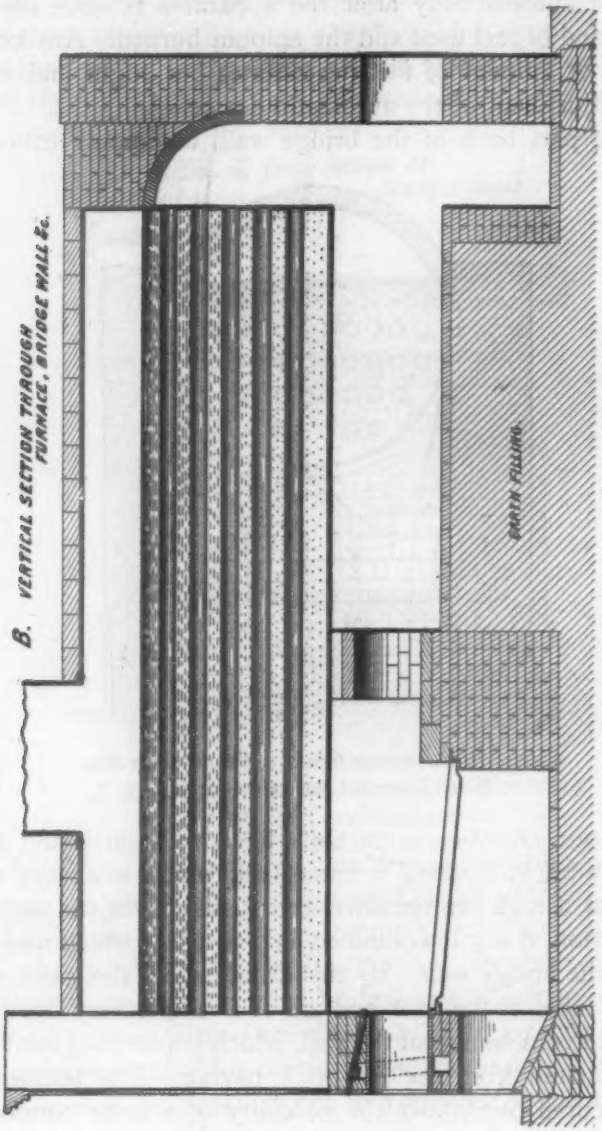


C. Cross Section through Furnace in Front of Bridge Wall,
Black Diamond smokeless furnace.

combustion chamber, is partially filled with earth and paved with fire-brick, forming a flame bed, which is always maintained at a high temperature, thus assisting in the complete combustion of any uncombined air and gases which may have passed the bridge wall. By this arrangement the gases entering the tubes at the back end are of a temperature due to the complete combustion of the fuel, which is provided for by the heat radiated from the fire-brick paving. The temperature thus secured overcomes the necessity of a large combustion

chamber, in which the gases are given more time to thoroughly mix and combine, the heat in this case greatly reducing the time necessary for the combustion to take place.

The arch and other highly heated surfaces providing the



Black Diamond smokeless furnace.

proper temperature, the air supply for complete combustion is obtained through the panel door and baffle plates shown in the front view of boiler. The door is provided with a damper hinged at its center and controlled by the automatic device shown on the left. By this arrangement the air supply through the front begins as soon as the doors are closed, at the time when most air is needed, in order to provide for smokeless combustion. The automatic device gradually decreases the amount of air supplied, by slowly closing the dampers in the doors and shutting off the steam operating the steam jets, which are provided for use in case very rich coal is used, or the demand for steam requires strong firing. The air thus injected is drawn through a passage concealed in the brickwork, thus heating it to a high temperature before permitting it to mix with the gases.

The automatic regulation of the air supply is a most essential feature in the economical production of smokeless combustion.

Practice proves that suitable means for maintaining a high temperature of the air and gases must be provided in order that perfect combustion can take place. The bridge wall and flame bed lining provide this, as just explained. The arrangement of bridge wall, flame bed, etc., is shown in the vertical section through furnace and boiler and in the small cut showing cross-section through furnace in front of bridge wall.

It is claimed for this furnace that it is constructed on correct scientific principles, and that it will both burn smoke and consume any kind of coal without smoke, and with any kind of chimney draft, while it has been shown to yield very economical results. The furnace is simple in construction and durable. (From data furnished by the manufacturers.)

THE ACME MECHANICAL AUTOMATIC STOKER.*

Mr. Wm. E. Gray [New York]:—The theory of smoke prevention, as well as the theory of combustion, has been so thoroughly and ably presented in the previous discussion of

* Manufactured by the Falls Rivet and Machine Co., Cayahoga Falls, O.

the smoke nuisance question, which has appeared in the *Journal*, that it will not be necessary for me to attempt to add anything to that phase of the subject.

The "Acme Stoker," which I have the pleasure of bringing to your notice, burns all grades of bituminous coal practically without smoke, and comes well within the limits of the strictest smoke ordinance. It is durable, economical, efficient and practical, and embodies in its construction several novel features.

An examination of *Figs. 1, 2, 3* and *4* will explain its mechanism and operation.

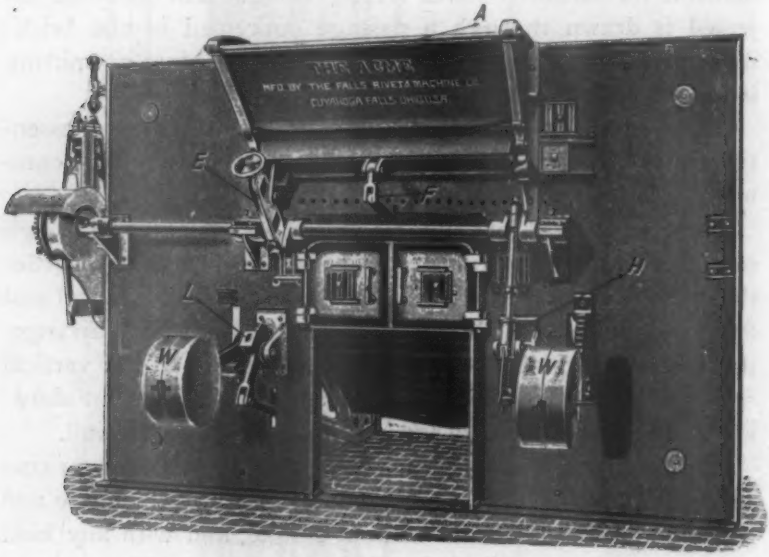


FIG. 1.—**Boiler front equipped with Acme stoker.**

In erecting the stoker in connection with any of the different types of boilers, the regular lower half of the front (as supplied for hand-firing) is replaced by a special cast-iron stoker front, as shown. In *Figs. 1* and *2* this front is shown with the grates in position for automatic stoking.

The stoker is operated by the small engine shown on the left-hand side. The hopper is filled with coal, which is pushed onto the dead-plate, *C*, and then down to the auxiliary

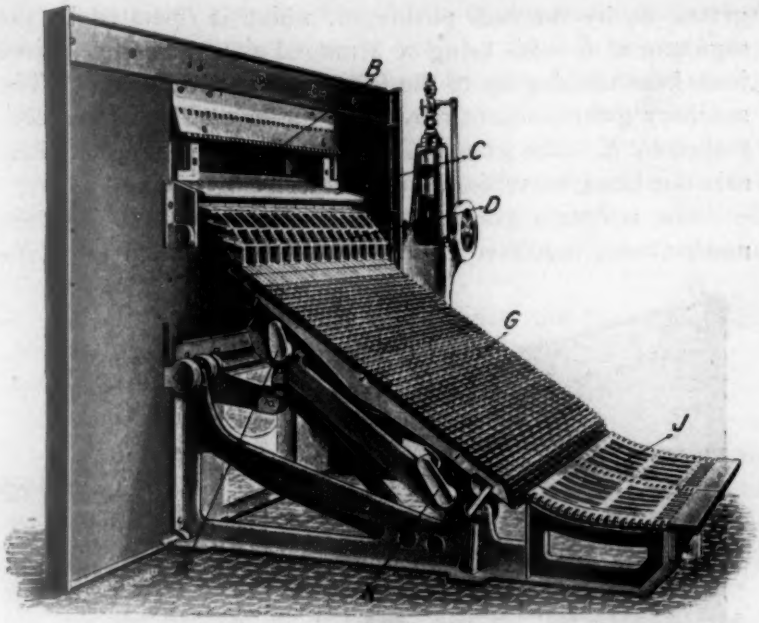


FIG. 2.—Acme stoker; grates in position for automatic stoking.

FIG. 3.—Acme stoker; grates dropped for hand-firing.

grates, *D*, by the coal pusher, *B*, which is operated by the regulator at *E*—this being so arranged as to give any desired feed, from nothing up to the full capacity of the stoker. The auxiliary grates, *D*, are moved by the lever, *F*, and are controlled by *E*. The grates, *G*, are 1⅛ inches wide, each alternate one being movable, the remainder being fixed.

The alternate grates are moved by levers, *K K*, their motion being regulated at *H*. First, they are raised above the

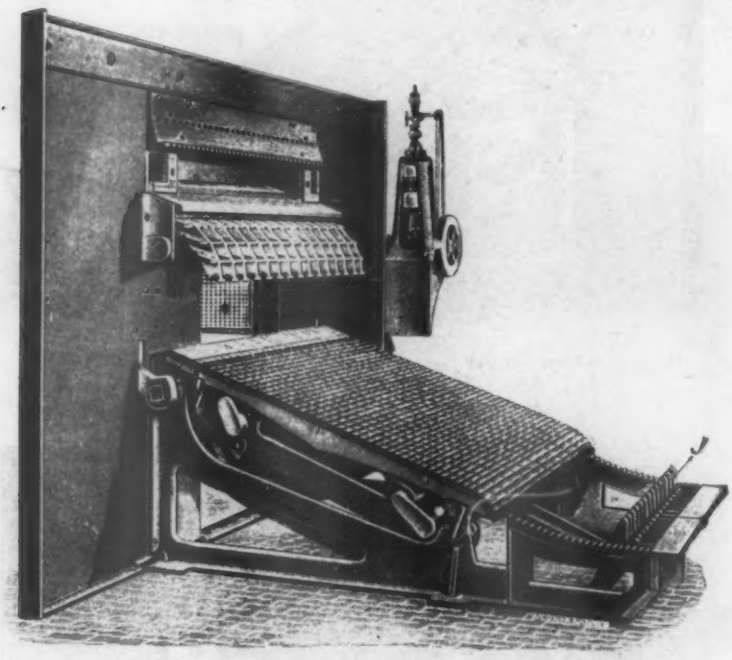


FIG. 2.—Acme stoker; grates dropped for hand-firing.

fixed grates and then moved forward, carrying the burning coal with them, afterwards dropping back to their original position.

The dumping grate is shown at *J*, *Fig. 2*, in position to receive the ash and clinker from the grates, *G*. This is controlled by the lever, *L*, and can be dropped, as shown in *Fig. 4*, to deposit the refuse in the ash-pit, which is then cleaned out in the ordinary way.

Figs. 3 and *4* show the stoker with the grates dropped to a position where they can be fired by hand in the ordinary manner. *W W* are counterbalance weights to assist in raising and lowering the grates *G*. The grates can be shaken by hand from the front by means of *H*. By this means there is no danger of loss of boiler service on account of accident to the stoker mechanism, and it also makes every part as accessible as in a plain furnace. It also greatly facilitates the starting of the fires.

In regular operation the coal is filled into the hopper, *A*, and from there fed to the dead-plate, *C*, where the coking is commenced; from there it passes to the auxiliary grates, *D*, for the completion of the coking and the full ignition of all the coal and coke, which is greatly aided by the extra large air space at this point. It then passes to the grates, *G*, where, as it burns, it is gradually pushed down to the dumping grates, *J*, at which point nothing remains but ash, this being dropped into the ash-pit at regular intervals.

For the prevention of smoke and the complete combustion of the volatile matter in the coal, an inclined fire-brick arch is started over the auxiliary grates, *D*, and carried back towards the bridge wall.

Methods of construction and attachment vary with the different styles of boilers, but it will not be possible to describe them in this brief abstract.

The "Acme Stoker" is a thoroughly practical smoke preventer, and as such has been presented to this Institute, in response to the invitation of your Secretary.

THE COLUMBIA MECHANICAL STOKER AND SMOKELESS FURNACE.*

MR. G. E. MANNING [Westfield, Mass.]:—This stoker is a simple and durable apparatus, which receives the fuel in bulk and feeds it mechanically at any desired rate to the furnace, and after consuming all combustible matter contained in the fuel, deposits the ash and clinkers in the ash-pit.

* Manufactured by the Columbia Stoker Company, Holyoke, Mass.

There are two vital features of this stoker which should have special consideration:

(1) The grate is stationary; there are no moving parts exposed to the fire and likely to cause expensive repairs and shut-downs.

(2) The coal is fed *under* the burning fuel, and, all

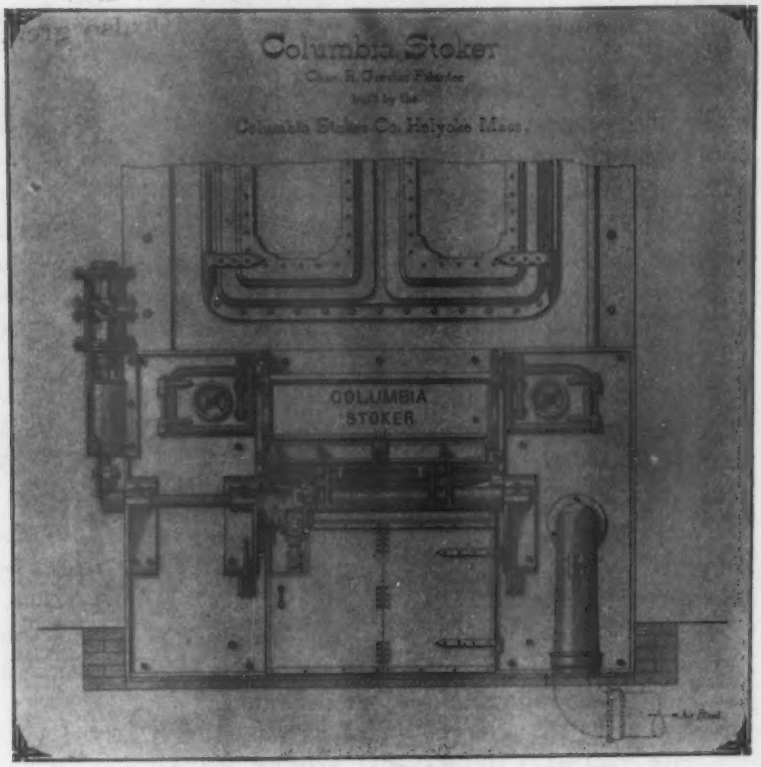


FIG. 1.—Front view of the Columbia stoker.

gases liberated therefrom being thoroughly mixed with the incoming air before passing through the incandescent bed of fire, a practically smokeless chimney is the result.

The operation of the "Columbia Stoker" is as follows:

Owing to the incline in the fuel passage, the fresh fuel will have a tendency to slide along the fuel plate directly on to the

blast grates, and in doing so, cause the bed of incandescent fuel, in course of combustion, to bulge or rise up; the heat from the burning fuel will slowly liberate the gas from the

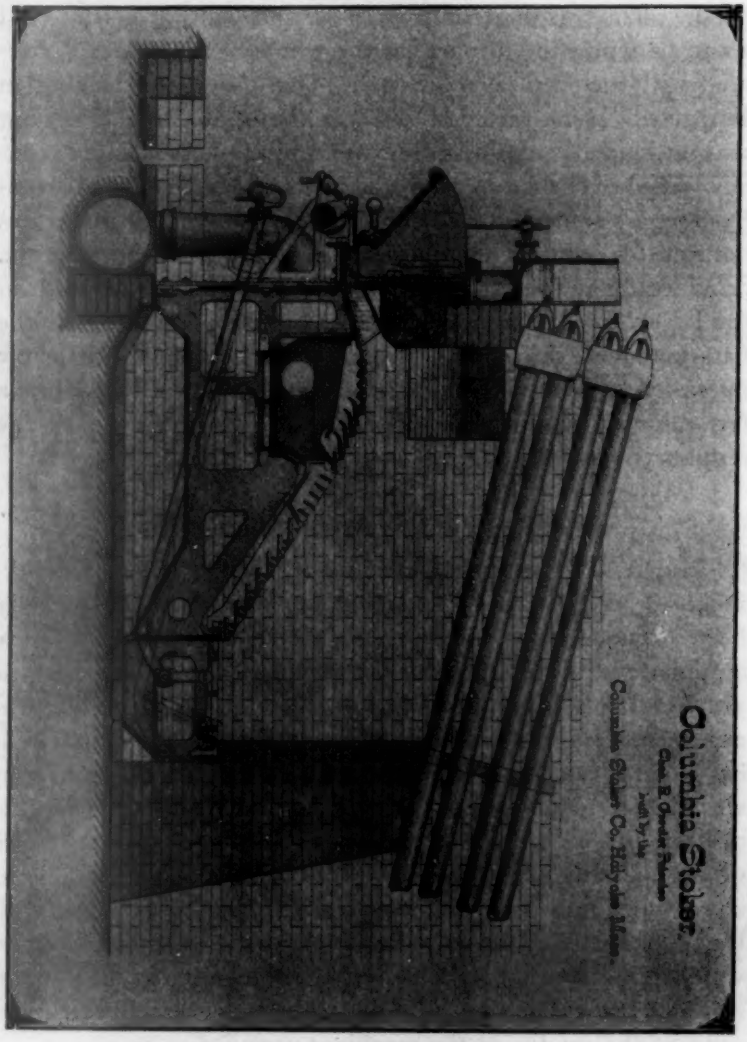


FIG. 2.—Section through furnace (Columbia stoker).

incoming fresh coal, and the air forced through openings in the blast grates in passing up through the fresh fuel will be

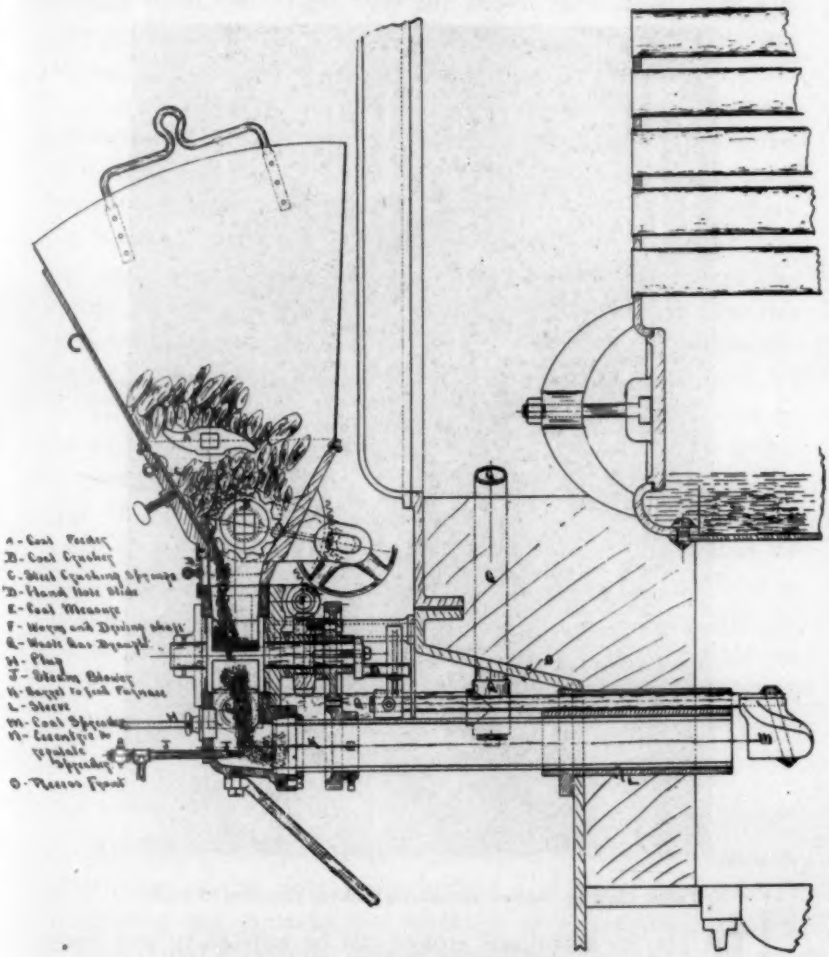
thoroughly mixed with the gases liberated before passing through the burning fuel above, resulting in a bright, clear fire and the complete consumption of all combustible elements in the fuel. The incoming fuel (on account of being pushed up the incline) is in a compact mass, and will not permit cold air to pass into the furnace, as the whole of the grates is covered with an even layer of coal. This process of feeding in fresh coal, which raises or replaces the ignited fuel, is going on continuously, the resulting ash and clinkers being gradually forced over the top on to the inclined grates for final combustion, air being supplied through the openings in the grates induced by ordinary chimney draft. A drop or dump grate, provided for the removing of clinkers and ashes, is located on the lower end of the incline grates, and is operated by handle bars extended through the front of the furnace. The whole operation of removing the clinkers and ashes only requires a few minutes, and can be done without interfering with the regular course of firing. (Correspondence.)

DAVIES AUTOMATIC STOKER AND SMOKE CONSUMER.*

MR. A. T. EASTWICK [Bridgeport, Montgomery County, Pa.]:— * * * The Davies Stoker Company has recently been organized for the purpose of introducing the Davies automatic stoker, which has been in operation for nearly a year, and has been thoroughly tested in regard to its efficiency in saving fuel and in increasing the boiler capacity. It has also proved to be very effective as a smoke consumer, but we wish to demonstrate more exactly its efficiency in this respect, and we are now equipping a Galloway boiler with this object specially in view, and we think we will soon be able to show more fully that our stoker will consume practically all the smoke from ordinary bituminous coal. In the meantime, we do not care to make any specific claims for the machine in this respect. We have no doubt, however, that it consumes most of the smoke, as the machines now in use show.

* Manufactured by the Davies Stoker Co., Bridgeport, Montgomery Co., Pa.

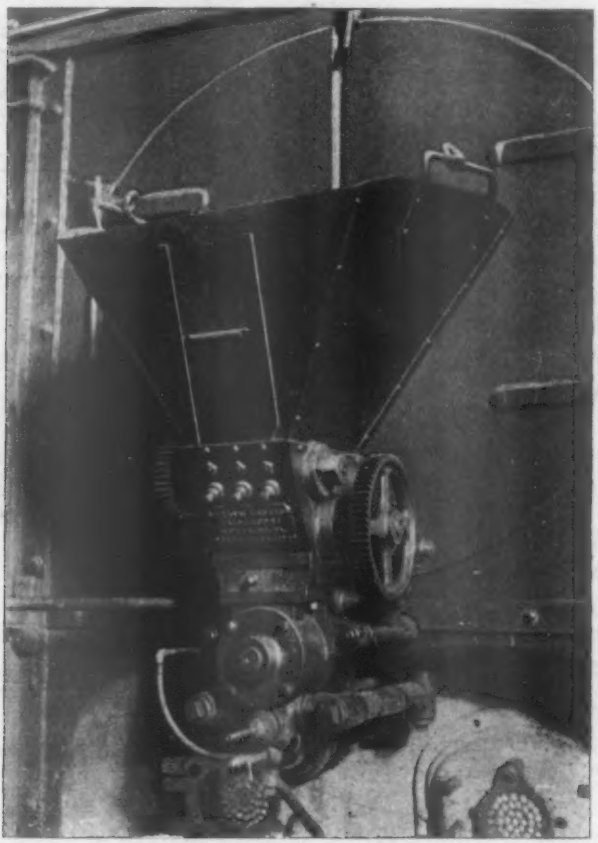
* * * The appearance and construction of the machine is shown by accompanying cuts. It was constructed for the purpose of saving fuel and increasing the boiler capacity, but, as we have already stated, it has also proved to be a smoke consumer. For the purpose for which it was con-



Vertical section showing parts of Davies automatic stoker.

structed it is very successful, showing a saving of 10 to 15 per cent. in fuel over hand-firing, and increasing the boiler capacity from 15 to 25 per cent.

The stoker is so simple in construction, and so much less expensive than any other stoker we have seen, that we feel it only remains for us to demonstrate more thoroughly its smoke-consuming merits to compete successfully with the leading machines of its kind in the market.



Front view of Davies automatic stoker, attached to boiler.

The Davies automatic stoker can be applied to any make of boiler or furnace, and is attached by bolting to the front plate with two bolts and a brace from below. A 5-inch hole is cut through the front plate and brick arch above the fire-door, and 15 to 18 inches above the grate bars, through which

is inserted a sleeve for the revolving tube, which carries the fuel into the furnace. When attached to a marine or upright boiler a 6-inch hole is cut through the water space into the fire-box, and a 6-inch tube inserted and expanded, in order to admit the sleeve for the revolving tube. The two 2-inch pipes leading from the feeder into the smoke flue draw back the greater part of the smoke and waste gas, and return it for consumption with the fresh fuel into the furnace.

It feeds the fuel into the furnace in any size required, from chestnut size to a powder, and is especially adapted for the burning of soft coals of all kinds. In attaching the stoker no alteration of grate bars or fire-doors is necessary, and boilers can be fired in the ordinary way if necessary. The grate surface may be reduced 15 to 20 per cent., and more steam obtained with the stoker than by hand-firing. It is easy on the brickwork, and does away with heavy bars and pokers for shaking the fires.

The operation of the stoker is as follows: The coal is placed in the hopper, and is carried in uniform quantity in the furnace through the tube *K* by means of the fine steam jet after reaching blower *J*. The coal is spread evenly over the grate surface by means of the deflector *M*. The quantity of steam required is very small, being about one-fifteenth of 1 per cent. A steam jet also creates a suction through pipe *Q*, which passes along the sides of the furnace to the rear of boiler, thus furnishing an excess of heated air. (Correspondence.)

DISCUSSION.

THE ECONOMETER OF MR. MAX ARNDT, OF AIX LA CHAPELLE.

Mr. Arthur Falkenau contributed to the discussion a description of the instrument known as "The Econometer," illustrating his remarks by reference to a specimen of the apparatus and a sectional view of same projected on the screen.

The instrument is a gas balance, and is designed specially to act as a continuous indicator of the percentage of carbonic acid gas present in the products of combustion from a steam boiler furnace, thus affording the operative in charge of the

furnace a visible indication at all times of the condition of his furnace fires.

The econometer is said to be extensively used in Germany, where its value as a practical appliance for promoting the economical combustion of fuel in steam plants is generally recognized.

The following description of the construction and operative features of the apparatus (in lieu of Mr. Falkenau's remarks, which were not furnished for publication) is abstracted by the Secretary from a report thereon, lately adopted by the Committee on Science and the Arts:

Referring to the accompanying cut, the apparatus consists of a balance, carrying at one end a gas vessel provided with a neck open at the bottom; a gas delivery pipe projecting upward into this gas vessel, being fixed and supported in it in such a way that upon the oscillation of the balance beam the gas vessel may move freely up and down without coming in contact with the upward projecting pipe through which the gas flows into the gas vessel.

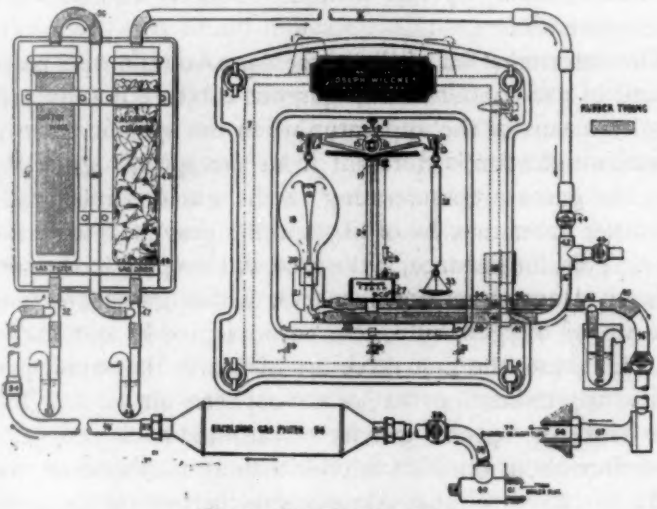
The gas vessel is balanced by a compensating vessel suspended from the opposite end of the beam, also open at the bottom, and equivalent to the gas vessel in its capacity in conjunction with small weights placed under a pan under the compensating vessel, that the pointer of the beam shall move to zero on the scale when atmospheric air is drawn through the apparatus.

The gas vessel being open at the bottom so that the pressure within it is always the same as that without, fluctuations of pressure and barometrical readings have not to be considered in the use of this apparatus; likewise fluctuations of temperature do not affect its action, because the gases passing slowly through the apparatus quickly take the temperature prevailing in the narrow gas passages.

The fluctuations which take place in the density of the gases round the fixed pipe in the gas vessel cause up-and-down motions in the latter vessel, which are shown by the pointer on the scale. This pointer is rigidly fixed to the beam so as to follow the movements of the gas balance; it oscillates in

front of a scale indicating units of weight by the distance between its dividing lines, or these distances shall, in conjunction with the pointer, indicate a particular percentage volume of a particular kind of gas in a gaseous mixture; for example, the instrument exhibited and described had divisions on its scale for indicating the percentage volume of carbonic acid gas for the purpose of ascertaining the percentage of such gas escaping in the products of combustion from a steam boiler furnace.

Two tubular orifices are provided, one for the inlet, and the other for the outlet, of gases, the former connecting by a



The Arndt "Econometer."

flexible tube with the vertical fixed pipe in the gas vessel, and the latter by a flexible tube with the cup-shaped vessel situated below the gas vessel. The source of the gas supply is placed in communication with inlet leading to the gas vessel and a suction apparatus of any suitable kind in communication with outlet from the cup vessel under the gas vessel. A portion of the air present in the casing is first drawn off, that is to say, the air is exhausted by suction to so much of a vacuum as corresponds to the strength of the suction at the cup vessel under the gas vessel. This rarefaction being obtained, the

gas to be weighed passes into the gas vessel, filling it, and then out of this vessel into cup vessel below.

The gas balance is enclosed in a casing provided with a glass front for the purpose of observation; this casing is provided with an aperture closable by a plug, upon the removal of which the weights may be adjusted as required. Further, at the top of the casing there is an aperture filled with cotton-wool for the gradual and continuous admission of atmospheric air thereto. The balance is, therefore, located in a nearly air-tight chamber, with its several parts so arranged that, when the gases to be weighed flow through a vessel forming part of the balance, it may operate without resistance and with greatest sensitiveness.

The determination of the percentage volume of a particular kind of gas contained in a gaseous mixture is only practicable by means of the apparatus when the specific gravity of the gas sought for is different from the specific gravities of the other gases preponderating in the gaseous mixture, but such other gases may be of like specific gravity among themselves. This, for instance, is the case with respect to the smoke gases of steam generator furnaces, which gases are mainly made up of oxygen, nitrogen, carbonic oxide and carbonic acid. Of these, the first three are of nearly the same specific gravity, approximating that of atmospheric air = 1. On the other hand, the specific gravity of carbonic acid = 1·52, and is therefore about one-half heavier than atmospheric air, and a smoke gas mixture must consequently be heavier the greater its contents of carbonic acid.

With perfect combustion of the carbon contained in the fuel and with the air of combustion measured in a theoretically accurate manner, the carbonic acid of the smoke gases amounts to about 20 per cent. of the total volume, but it is less than this when the air of combustion is supplied in a larger quantity. If now the zero line of the scale has such a position that it coincides with the pointer when only atmospheric air is present in the gas vessel; if, further, the end line or division of the scale has such a position that it coincides with the pointer when atmospheric air, mixed with carbonic acid to the

extent of 20 per cent. of the total volume, as determined by a chemical analysis, is drawn through the gas vessel; and if, further, the scale has twenty corresponding divisions, then the movement of the pointer from one division to another will correspond to the difference in the weight of the gaseous mixture in proportion to the percentage volume of carbonic acid, and accordingly, in the practical use of the apparatus, that is to say, when smoke gases are being conducted through the gas balance, the contents of carbonic acid, as indicated by the pointer in a sufficiently accurate manner for practical purposes, may at any time be read off from the scale direct. If, for instance, the pointer points to the division line marked 12 on the scale, this would indicate that the smoke gases drawn through the vessel contain 12 per cent. in volume of carbonic acid, that is to say, the volume of the latter would amount to 12 per cent. of the whole volume of the smoke gas mixture.

If the smoke gases of a steam generator furnace when passing to the chimney have a temperature of 270° C. (518° F.), and 12 per cent. of their total volume consists of carbonic acid, the loss of heat amounts only to about 15 per cent., but if at the same temperature the carbonic acid contents amount, for example, to only 4 per cent. of the volume of the waste gases, this would show a loss of heat of about 45 per cent., due in a great measure to the heating of an excessive quantity of air for the combustion of the fuel. Hence, it results that the gas balance herein described is of great importance as a controlling apparatus for steam generator and other furnaces, and also for obtaining the specific gravity of other gaseous mixtures by direct weighing.

A practical test of this instrument was made* at the Baldwin Locomotive Works, in this city, with results of a very satisfactory character. The boiler furnace, from which the supply of gas was taken, was one in which anthracite coal was used. The boiler was of the Babcock & Wilcox manufacture, and its furnace setting was in no respect different from their ordinary practice. The indications of the econometer were

* For the details of this test, consult Report No. 1973, Committee on Science and the Arts.

checked from time to time by chemical analyses of the flue gases. These analyses were by Prof. Harry F. Keller, Ph.D., of this city; each analysis was made immediately upon the withdrawal of the samples and at the place where the other tests were being conducted.

These comparative tests demonstrated the substantial accuracy of this instrument. The recorded variations show discrepancies so trifling that, if the econometer were used in the management of steam boiler furnace fires, no considerable loss would occur by reason of the difference between the econometer reading and the chemical analysis. A saving in fuel would result because of a better and more intelligent management of fire and damper, allowing less surplus air to pass through the furnace than would ordinarily be the case.

The econometer works continuously and shows automatically the percentage of carbonic acid in the gases, thus enabling the firemen to see at all times the more or less favorable conditions of combustion.

MR. JAMES CHRISTIE:—I desire to emphasize the statements made this evening—that the greatest source of loss in the furnaces of steam boilers can usually be traced to the influx of an excessive quantity of air. Combustible gases will sometimes be found in the discharge from boilers having limited combustion chambers and small fire tubes. But in ordinary conditions, with stationary boilers of the usual types, the loss from unburnt gases is generally insignificant. If we could burn all the combustible in coal, and control the admission of air nearly to theoretical requirements, say little over 12 pounds air per pound of carbon, analyses of the discharged gases would indicate over 20 per cent. of CO_2, and the free oxygen would be nearly nothing. If these gases escaped below 500° F., we should evaporate over 14 pounds of water from the boiling point of water to steam at atmospheric pressure for each pound of combustible. This subject was carefully studied by the late Eckley B. Coxe, and the statement just made by the representative of the company handling his stoker, that they have found flue gases to analyze 2½ per cent. free O and 16 per cent. CO_2, is a very remarkable one, and a

degree of excellence I have never found. An analysis of 10 per cent. each for O and CO_2 is probably near the average result in ordinary combustion.

Loss through excessive dilution of air is a frequent result of improper firing, especially when the grate surface is excessive; or it occurs from leaky boiler casing, and is an argument in favor of a forced blast, instead of pulling from the rear by natural draught.

Loss from this cause is common in some of the stoker systems now in vogue, and its repression should be studied by those who desire to win favor. As an illustration, I give the condensed results of a recent extensive series of tests on boilers, both hand-fired and mechanically stoked. I am not interested in any particular boiler or stoker, therefore will not discriminate by giving names.

About twenty tests in all were made on boilers of identical make and setting, using bituminous coal, in their daily routine of work:

Method of Firing.	Water Evaporated from and at 212° per lb. of Combustible.	Efficiency of Boiler.	Analyses of Gases.			Air per lb. of Combustible.	Appearance of Discharge at Chimney.
			CO_2	O	CO		
Hand fired .	10·6 lbs.	70 p.c.	9·00 p.c.	11·13 p.c.	·54 p.c.	25·78 lbs.	Dense black smoke
Stoker No. 1	11·4 lbs.	76 p.c.	8·98 p.c.	8·69 p.c.	·59 p.c.	22·48 lbs.	Very light smoke
Stoker No. 2	10·2 lbs.	68 p.c.	5·8 p.c.	13·2 p.c.	·06 p.c.	40·02 lbs.	Smokeless

No boiler test is complete or determinate without analyses of the waste gases, and these frequently reveal, as in the above instances, a prolific source of previously unsuspected loss.

Mr. Isaac Bowe [Chicago]:—Your note, inviting me to participate in the discussion of the smoke question at the meeting of the Institute on September 15th, is at hand, also a copy of the past discussions of the smoke question. I shall not be able to be present in person, but send the following contribution, which you are at liberty to use as you please.

I wrote to the Board of Health of your city last spring, making inquiries whether there was any ordinance in refer-

ence to smoke, and was informed by the President of the Board that there was none, but that there had been some discussion of the advisability of such an ordinance. I did not gather from his note that the matter was in such active shape as your note indicates, otherwise I should have been only too glad to have lent my co-operation.

I was drawn into this smoke business by the fact that I was frequently consulted professionally about better and more economical methods of burning soft coal. In my investigations in that line I was early led to the point that the burning of coal without smoke must be one of the requisites of better work. For twelve years I have had an intimate experience of the joys and sorrows of the smoke business, and have faith to believe that my experience may be worth something to you in avoiding stumbling blocks.

I will take the liberty at this time to give you briefly the experience of Chicago and a little of my own. * * *

The Chicago ordinance has been in force for over fifteen years, and very much has been accomplished in cleaning up the city. I think I am safe in saying that we are making fully 70 per cent. less smoke than formerly in the down-town district. Sometimes I wonder at what we have accomplished when I look back over the way it was done. The friends of decency and cleanliness have kept the ordinance alive, not, however, without a good deal of opposition. This has often been pretty stubborn and led by representative and influential men. The protests—when all the chaff was sifted out—were generally found to be not so much against the ordinance as against the way it was enforced.

The smoke inspectors enforced the ordinance just as any other ordinance was enforced; namely, from the standpoint that it was not the duty of an official to show how to comply with the law, but to compel obedience. Plainly speaking, the official attitude was this: "Your chimney smokes. Stop it, or I will haul you into court and fine you."

There is this to be said about this way of abating smoke. It is very simple, and saves lots of work, and any simpleton can fill the bill as smoke inspector, on this interpretation of his duties.

The opposition also claimed that this was the wrong way to get ready compliance and good results; that men who knew something about boilers, coal and the demands of a steam plant should be appointed as smoke inspectors. They charged that the inspectors cared not so much for the cleanliness of the city as for the devising of means for raising revenue improperly for their own pockets; that the owners of certain smoke devices, oil-burning devices and special brands of coal, said to be smokeless, were doing a suspicious amount of business, not on their merits, but as the direct work of the inspectors. However that may be (and there appears to have been some truth in the charges), the belief became general that the inspectors were crooked. Some owners of plants acknowledged they had changed furnaces, allowing themselves to be blackmailed, to get rid of the city, as they put it; others went boldly up to the captain's office to find what burner would satisfy them. They were told, as boldly, the city recommended nothing, but a way was found to convey the inspectors' wishes.

If experience is worth anything, you will readily see that it is not so important what ordinance you recommend, as to get the confidence of owners of steam plants that an honest effort is being made, and in an honest way, to get rid of the nuisance. It is much easier to keep confidence than to restore lost confidence.

I have essentially stated I did not believe a "smoke ordinance" should be enforced as ordinary laws are enforced. Instead of putting a man on the roof of a high building, with a spy-glass, to watch chimneys, I believe that men should be sent out whose duty it is to visit the boiler rooms, and that these men should be competent to suggest and advise what is best to do.

There are many reasons why this course is best, and a few of these I will mention. Correct coal burning, that is, good combustion, is a nice chemical problem, but the men who burn the coal are not generally men who have very much education, except what they have picked up in the boiler room. They know very little about the union of carbon, hydrogen and

oxygen. They do know that they have got to do certain work to get steam and keep it. To get the same results *and* good combustion, such men need instruction. Every furnace owner knows that the best results are obtained by his furnace when operated by a certain method and that different coals require different handling. Will inexperienced men operate a furnace, then, in a proper manner? Inexperienced men having no knowledge of firing, no knowledge of the particular burner they are called to operate, and, in fact, no knowledge of any burner, are sent into the boiler rooms here, to work, every day. Shall the owners of plants be persecuted and prosecuted until these men have learned what to do?

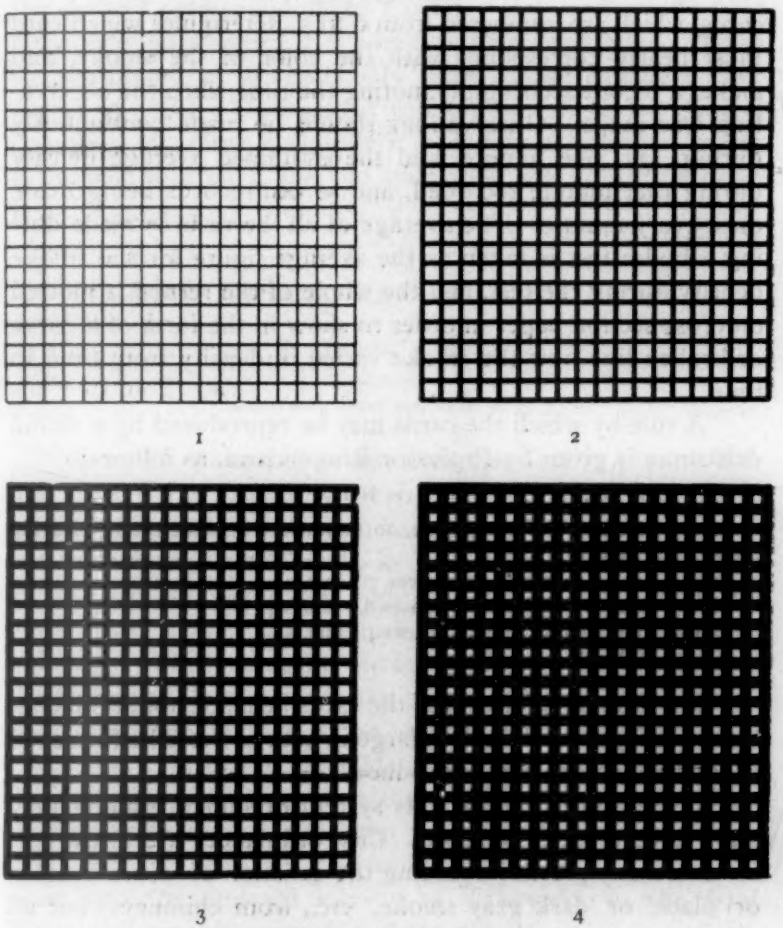
Let me further add that whatever ordinance is passed, compel the inspector to keep an open book of record; for just so sure as his work can be concealed, the owner of some cheap, inferior device, will purchase information and the inspector will be corrupted to pass it. Lastly, don't advise any St. Louis ordinance, as it will both hamper competition and invention. But very few men in the furnace business can afford to stand the expensive test which the St. Louis ordinance calls for. The tests of furnaces are utterly useless in actual practice. A furnace may give the very best results both for economy and prevention of smoke in a test, working under the most favorable conditions; but when put into the actual daily practice of a steam plant, it may, and often has, proved an utter failure. * * * (Abstract of a letter addressed to the Secretary.)

THE RINGELMANN SMOKE SCALE.

THE SECRETARY made reference to various systems in vogue for determining the relative density or blackness of smoke delivered from factory chimneys, some of which were in use with official sanction in connection with the enforcement of smoke prevention ordinances.

One of these, proposed by Prof. Ringelmann, of Paris, is said to have come somewhat extensively into use in Europe, and is favorably spoken of by Mr. Bryan Donkin, of London, who has found it useful in connection with tests of steam

boilers and of smoke-preventing appliances. Mr. Donkin has furnished to *Engineering News* a description of the Ringelmann system, which is herewith reprinted by permission. The method appears to have the merit of great simplicity and of sufficient accuracy for practical use:



The Ringelmann smoke scale.

"In making observations of the smoke proceeding from a chimney, the four cards, on which are printed a network of black lines, together with a card which is printed in solid black, and another left entirely white, are placed in a horizontal row

and hung at a point about 50 feet from the observer, and as nearly as convenient in line with the chimney whose smoke is to be observed. At this distance the lines become invisible, and the cards with printed lines appear to be of different shades of gray, ranging from very light gray to almost black. The observer glances from the smoke coming from the chimney to the cards, which are numbered from 0 to 5, determines which card most nearly corresponds with the color of the smoke, and makes a record accordingly, noting the time when the observation was made. Observations should be made continuously during, say, one minute, and the estimated average density during that minute recorded, and so on, records being made once every minute. The average of all the records made during a boiler test is taken as the average figure for the smoke density during the test, and the whole of the record is plotted on cross-section paper in order to show in the form of a curve or broken line how the smoke varied in density from time to time.

"A rule by which the cards may be reproduced by a skilful draftsman is given by Professor Ringelmann, as follows:

Card 0, all white.
Card 1, black lines 1 mm. thick, 10 mm. apart between centres, leaving spaces 9 mm. square.
Card 2, lines 2.3 mm. thick; spaces 7.7 mm. sq.
Card 3, lines 3.7 mm. thick; spaces 6.3 mm. sq.
Card 4, lines 5.5 mm. thick; spaces 4.5 mm. sq.
Card 5, all black.

"Mr. Donkin advises that the cards be made about 8 inches square each, or four times as large in area as those he furnished us, and which are here reproduced.

"It appears to us that this system of smoke grading may serve a very useful purpose. City ordinances are already in force in many places forbidding the emission of 'dense' smoke, or 'black' or 'dark gray smoke,' etc., from chimneys; but all such phrases are indefinite and can be too easily perverted to let favored parties escape and to punish those who are not favored with a 'pull' and will not purchase immunity. A city ordinance providing that the density of the smoke emitted by any chimney should not exceed that corresponding to No. 2

on the Ringelmann scale, would give a definite standard by which smoke inspectors could be governed. To burn soft coal without producing any smoke is impossible under practical conditions; but, on the other hand, proper appliances and good management can certainly prevent the emission of smoke of the density corresponding to Card 4. If a smoke ordinance requires impossibilities, it is bound to be a dead letter. If it is so interpreted as to reach only those whose chimneys emit smoke of positive blackness, it will not help much the general condition of a city's atmosphere. This scale, however, makes it possible to draw a line and state what will constitute good practice in smoke prevention."

GEOGRAPHY OF PRECIOUS STONES.*

By George F. Kunz.

(*Concluded from vol. cxlv, p. 35.*)

Next in point of value to the ruby is doubtless ranked the beautiful green emerald. The remarkable history of emerald production has already been referred to as anciently from Mt. Zabarah, in Upper Egypt, and then the locality was completely lost sight of and abandoned for many hundreds of years, during which the source of emeralds was unknown. Then came the discovery of the New World, and the finding of these gems in the possession of the natives, obtained from the mines at Muzo, near Bogota, United States of Colombia. All of the emeralds sent to Spain at the time of the first conquest were from these mines. From that time these Bogota mines have been the principal source of this gem. For two centuries they were the only one, but about 100 years ago the emerald locality of Takowaja, in the Ural Mountains, was discovered, and for a time was a second important source. But the Ural mines have been for thirty years unworked, owing to the enormous privilege demanded by the Russian Government; and until this is changed, no

*A lecture delivered before the Franklin Institute, April 9, 1897. Copyrighted by George F. Kunz, 1897.

more emeralds are likely to be brought from that locality; as the fine log roads have gone to decay, and the thousands of tons of chrysotile, or asbestos, as it is erroneously and commercially called, recently discovered at a locality near the old mines, have more commercial value than the former output of the emerald mines.

It is very possible that many of the fine emeralds now in the Orient were taken there and bartered by the great jeweler and traveler, Jean Baptiste Tavernier, in the middle part of the seventeenth century.

The immense hexagonal sections of emerald that are in the jewelry that was captured from King Thebaw, of Burma, may date from this time, when the ruby mines were visited by Tavernier, and he may have exchanged the emeralds for Burma rubies.

When the emeralds of New Grenada were brought to the knowledge of Europe, it was assumed by many that here must be the long-lost source of these beautiful gems, and that in some way they must have been carried across the Pacific to the East Indies, and thence found their way to Europe. Some curious treatises were written on the supposed intercourse between America and Asia, based on this hypothetical foundation.

An equally curious discussion has been carried on for the past twenty-five years, attributing to the Mayas a Burmese origin, because jadeite is found in Burma and Mexico, and the Mexican source has not been discovered; but it may be any day, as jadeite undoubtedly has some place of occurrence in Mexico or Central America.

Garnets were evidently one of the early articles of commerce from the East, although in modern times the principal center of garnet trade and garnet cutting has been in Bohemia. Russian excavations in the Caucasus have brought to light garnets, originally very beautiful, that give evidence of a very ancient trade, probably with India. The same may, perhaps, be said of many garnet articles in other parts of Europe found in tombs of Roman, Celtic, old English, Merovingian and Carlovingian date, and Etruscan and Byzantine remains.

Among these are garnet slabs or plates, garnets set in gold, as well as beads, which may have been brought by traders from Egypt or Pegu or other parts of India, rather than from Bohemia, as they are the almandine and not the pyrope variety of garnet. Six hundred establishments in Prague, Meronitz, and other parts of Bohemia give employment to 8,000 persons in the garnet industry.

Turquoise furnishes a marked illustration of the geographical changes of gem production. For ages it was only found near Nichapour in Persia, and in the Sinaitic Peninsula, and generally sold at Teheran, Cairo and at the great Russian fairs, held annually at Nijni Novgorod and at Troitsk, in Orenburg. It was carried on camels or horses to the Volga, then by steamer to Nijni Novgorod. From there it went all over the world. The Arabian mines have been largely abandoned, and all the Eastern localities had lately begun to fail, under the primitive methods there in use. But just at the time when the old sources were ceasing to yield, turquoise was discovered at several points in our own country—in New Mexico and Arizona; and the mining and production of this Oriental stone has already become an important and promising industry in the far New West. But these very mines, as now appears, were extensively though rudely worked by the pre-Columbian peoples of Central America and Mexico, and their product was highly prized and wrought into various singular objects of ornament and distinction. The stone tools and piles of *débris* of the ancient workers are conspicuous at the numerous old mines; and though these are largely abandoned and forgotten, yet traditions linger among the semi-civilized tribes of the Pueblos, of the value and sacredness of this stone to the descendants of the Aztecs and Montezuma.

Two rooms in New York office buildings, receiving packages from the mines by mail or express, sell annually more turquoise than did a host of Persian or Armenian traders, frequently traveling thousands of miles to effect sales.

As to the future of turquoise—it is a beautiful stone, and will always find a sale, although occasionally of unstable color. As an old jeweler once said: "If a lady wants a turquoise, you

can tell her a dozen times that it may change color, and that it is unstable, but she will buy it anyway." The American mines to-day yield ten times the greatest output of Persia in her palmiest days. Egypt is again furnishing fine stones. Australia may enter as a producer, and even Peru and Bolivia may yield as much as the United States, if the localities are discovered where the turquoise objects in the Montez and other Bolivian and Peruvian collections came from.

Among the curious and interesting archæological uses which turquoise has been put to are the clam shells, encrusted with turquoise to resemble toads, and the human skulls, encrusted with turquoise, now in the Brunswick collection, in the Chrystie collection in the British Museum, and the Pigorini Museum in Rome; and double-headed animals resembling tigers, encrusted with turquoise, that were brought from Mexico by Humboldt, and human teeth, ornamented with turquoise, from Peru, are in the Berlin Museum.

A somewhat similar record, though without the romantic interest of prehistoric and sacred use, may be given in regard to the beautiful gem opal. This stone must have been well known to the ancients, as far back at least as Roman times, for the eminent naturalist Pliny describes it with great enthusiasm and great distinctness; but the opal for which Nonnius preferred banishment rather than parting with was evidently another gem, perhaps fractured quartz showing iridescent coloring, called "iris." The principal source has for three centuries been in Hungary, where opal-mining has been an important industry. For a long time the opal was under a cloud, owing to Scott's ill-fated Anne of Geierstein. But with the discovery of new mines, it has become popular even beyond the great supply, and thus the beauty and the profusion of this gem have dispelled the superstition of a century.

Opal is, however, largely a gem of the New World, some of the finest material coming from Mexico and Honduras, and a single Idaho opal has sold for $1,000.

For some years past, also, magnificent opal has been brought from Queensland and from Wilcannia, New South Wales. In the latter country a journey of 600 miles from

a railroad is made to procure the gem, and beautiful precious opal replaces wood and shells, atom for atom. A recent fine opal of 271 carats was of this character. In both of these localities are found opals of matchless beauty in such abundance as to rival the greatest yield in the Hungarian mines, where the output was regulated to maintain the price.

To enter into an account of the distribution of the many different gems and precious stones that are included among the varieties of quartz would exceed the limits of this lecture. I can only refer to a few of the most important and familiar of them.

Among these we may note, first, the clear transparent quartz itself—the mineral in its purest condition—known as rock crystal, or sometimes crystal, simply. Common as this substance is in mineralogy, it is rarely found in pieces of sufficient size and clearness combined, to make it of value in the arts. It is wrought into ornamental objects—notably the crystal balls of Japan, which have long been celebrated articles of *vertu* among collectors of Oriental art. Recently these have also been cut from quartz found in Brazil, Madagascar and the United States; though but little of the American material is fine enough for this purpose.

The many centuries in which Japan was closed to the world led to an accumulation of crystal balls; but now forty years of tourist buying has drained the country, and the price has advanced fully 500 to 1,000 per cent. for perfect crystal balls over 4 inches in diameter. A perfect 6-inch ball commands $10,000. The Ames ball, at the Boston Museum of Fine Arts, is 7⅛ inches in diameter, weighs 20 pounds, and cost over $20,000, and yet has not the absolute perfection demanded by the collector.

Pliny describes how the quartz crystals were found in caverns in mountain sides among the Swiss Alps; how they were discovered and procured by letting men down by ropes, and then taking out the crystals. This mode of exploitation is carried on to this day in this prolific locality. During the Renaissance in Italy and Austria this was a favorite art material, and the treasures of the Louvre, the Prado in Madrid,

the Vienna, Dresden and other museums contain great quantities of priceless quartz coupes, caskets and other similar objects. The Thirty Years' War entirely broke up this art in Prague, then the great center for the work; so completely, indeed, that I was unable to obtain even a single fact regarding it in the archives of that ancient city.

In the fourteenth and fifteenth centuries, some Romans founded the industry of cutting agates and Tyrolese garnets in Fribourg, in Baden; but the frequent quarrels and raids of the knights of that time so disturbed the industry that it was withdrawn to the village of Waldkirch, a short distance from Fribourg, where 120 men and women are employed at the present time.

It was not until 1536 that agate cutting was brought still farther northward to Idar and Oberstein, in the Duchy of Oldenberg, where for 15 miles along the river Nahe the agate-cutting industry flourishes, and where now fully 30,000 people are dependent on the industry.

Doubtless many of the Cinque Cento gems, and probably some of the earlier Roman ones, were found in the amygdaloidal rocks in this vicinity, and this finding of the agates led to the founding of the industry there.

But now finer agates and similar stones are brought to these places from all parts of the world, principally from Brazil and Uruguay. Collectors go out to South America, New Zealand and the uttermost parts of the earth, and there search for these agates, with characteristic German patience, until they have succeeded in gathering a large quantity of material, which is then exported to Europe. It is then worked up at Oberstein and Idar, and wrought into an endless variety of ornamental objects, which are once more sent on their travels, and exported to all the continents—different kinds of articles being manufactured regularly for the needs and fancies of different nations and tribes, civilized and savage. Nearly all the colors are the result of staining the gray and bluish chalcedony. Thus, the agates of South America are carried to Germany, and thence find their way not only to our country and over Europe, but to the remotest parts of Africa and Asia.

When the agates are well marked and even, they afford opportunity for the cutting of cameos, and the production of many beautiful effects. In 1870 new processes were discovered, by which any piece of chalcedony could be altered into any color of onyx. Formerly onyx was always the juncture of two natural parallel layers of agate.

Next to the metallic coinage of the ancients, we have a higher art, and more history of the periods from the earliest times, recorded on the quartz gems than in all other substances combined.

In Konigsberg, Prussia, a single firm controls the amber industry, and annually handles 132,000 pounds of amber, employing 1,500 people. This firm has employed for many years Professor Klebs to gather interesting amber specimens. As a result, they have a remarkable museum entirely of amber and amber articles, which is of especial ethnological interest, since they furnish amber to India, Persia, Egypt, Tripoli, Senegambia, Corea and South America, and exhibit a complete ethnological collection of amber from wherever it has been used in any time.

One of the most interesting of the semi-precious stones is that known as jade, including two species—jadeite and nephrite. These have been favorite materials for ages with many semi-savage peoples throughout the Orient, and venerated as almost sacred in China, under the name of *Yu*. An extensive ancient commerce in jade existed throughout Asia; one of the gates of the Great Wall being known as the *Yu Gate*, or jade gate. The Chinese used jade for a variety of figures and statuettes, and traded it to India, where it was wrought into other forms, as amulets, sword hilts, etc., and often inlaid with jewels and gold. Many such objects from Persia are believed to be part of the immense spoil of $750,000,000 brought thither by Nadir Shah in 1751, after his conquest of Aurungzebe. Such are a jeweled jade mace-head, which is now in the American Museum in New York, and many fine specimens in European collections. A dark green variety, called Oceanic jade, was largely used in New Zealand and the South Pacific; and prehistoric jade celts, etc., occur through-

out Europe. A few remarkable jadeite objects have been found in the New World, but there is no reason to think that they came from Asia, as no other indications of such intercourse appear. Jadeite, indeed, occurs in worked objects, and we have not yet traced it to its finding place in America, but we will surely do so ere long, just as Lieutenant Stoney found jade in Alaska.

A recent meteor-like passing of a gem across the firmament of fashion, rising to the zenith and then falling out of sight from the height it had reached, is curiously seen in the "tiger-eye," a yellow-brown quartz cat's eye, from Griqualand, South Africa, selling from $6 to $10 a carat to jewelers only, but owing to the competition of two rival dealers, who sent cargoes of it to the London market, the price fell to $1, then to 25 cents per pound by the quantity, within two years' time; and to-day it is only used in the cheapest jewelry.

Of course, in speaking of commerce in precious stones, there is no question of a great carrying trade such as we think of in food products or manufactured goods; but the questions are those that pertain to security of transportation, and greatly concentrated value. Precious stones possess three requisite qualities to make them important articles of commerce: (1) They are desirable. (2) They are scanty of supply. (3) They are readily transferable. But these same qualities also render their transportation hazardous, and require extreme precaution. In regard to the great value of precious stones, a few recent figures may not be uninteresting. A pearl necklace, weighing $1\frac{2}{5}$ ounces, is valued at $90,000. A diamond necklace, weighing $1\frac{1}{5}$ ounces, at $45,000. A small red diamond, of $\frac{3}{8}$ carat, was sold for $1,200, or at the rate of $450,000 per ounce. A ruby, of $9\frac{3}{8}$ carats, at about $50,000, or a value of $723,000 per ounce.

In regard to the small size or minuteness of some cut stones: Perfect brilliants are cut from 200 to 250 to the carat; in other words, from 30,000 to 37,000 to the ounce; and rose diamonds 2,000 to the carat, or 302,000 to the ounce. The highest price paid in modern times for a single stone was by the Nizam of Hyderabad, in 1892, for the Imperial or Vic-

toria diamond, of 180 carats, £400,000, or $2,000,000, for a stone weighing $1\frac{5}{8}$ ounces; in the United States $200,000 for a pearl necklace, and a few years since over $320,000 was paid in the United States for a diamond necklace.

In former times the gem merchant was peculiarly exposed to perils, and could only travel in the company of a caravan, or under the protection of friendly chiefs and rulers. At the present day, however, the jewels of India, Africa and Brazil are sent over the world in a different way, and with far greater safety. The caravans of the East and the diamond convoys of Brazil and the armed secret messengers of former days are replaced now by the International Postal Service. Almost all of the $360,000,000 worth of rough diamonds taken from the South African mines have been sent to London by mail, and packages of rough stones are constantly going to and fro between the great diamond cutters of Europe, apparently without a thought of risk. The comparison with our own mail service is not complimentary to the latter.

A somewhat similar contrast may be noted between former and present conditions in regard to the keeping of precious stones and articles of jewelry. In past times the owners of such treasures had to depend either upon concealment or armed force for security in their possession.

Many of the great Oriental collections are kept in out-of-the-way rooms. Sometimes the gems are wrapped in rags, or concealed in ginger-jars, old boxes and out-of-the-way places, so that even an intimate visitor may be a guest for weeks and only occasionally see a jewel; not unless he has the entire confidence of his host are the treasures gradually brought to him one at a time, from their queer and uninviting hiding-places.

By means of safety deposit boxes, the jewels of the private owner or dealer are safer than the jewels of the imperial houses ever were, even under armed guards, or in the Duke of Brunswick's impregnable room in Paris. By the expenditure of a merely nominal sum, the family jewels now have absolute protection from theft or fire, which the monarchs of foreign lands, with their hosts of servitors, often failed to attain.

A few words as to some radical changes immediately

affecting us, are brought in by the subject of diamond cutting in the United States. Since 1868, we have imported about $200,000,000 worth of cut diamonds, with a duty of 10 per cent. The original rough stones could not have cost more than one-half; and if the cutting had been done in this country, allowing a liberal margin for profits and interest, it would have given employment to 5,000 men for the past twenty years, at the average yearly wages of $1,000.

It was the simple presentation of a cat's-eye engagement ring by the Duke of Connaught to his bride, in 1878, that led to a great search for the phenomenal gem, and resulted in all the phenomenal gems being sought for by Dame Fashion, stimulating the public interest in the fancy for semi-precious stones, which has increased greatly since our Centennial Exposition.

Formerly, jewelers sold only diamonds, rubies, sapphires emeralds, opals, pearls, garnets and agates, but now it is not unusual for the mineralogical gems, such as zircon, star sapphire, star ruby, tourmaline, spinel or titanite to be called for, not only by collectors, but by the public, whose taste has advanced as much in the matter of precious stones as it has in art.

Spinel is the most valuable of the semi-precious stones, and it is one of the few minerals that are ornamental and beautiful enough for gems in their natural state. Another recent gem is the wonderfully beautiful green garnet, or demantoid, found in the gold washings in the Ural Mountains. This rivals the emerald when small, inasmuch as it has a play of fire absent in the queenly green gem. Because the name olivine strikes the ear as more pleasant, this gem has lost its identity and nearly everyone persists in calling it olivine, a name that does not belong to it.

The rapid mode of travel in modern times, when a trip around the world can be made in comfort in less time than a trip to India one way could be made in previous times, results in the gems being sent to markets instead of the traveler seeking the gems. Formerly, the dealer was a traveler, and returned with wonderful tales of the East. To-day, agates of Oberstein, opals of Australia, tiger-eye and diamonds of

the Cape, the gems of Ceylon and Burma are scattered to the uttermost ends of the world within three months, and the gems of the East go to the far West, until, as with civilization, there is no more West, or more correctly, the West is East, or rather they meet on the Pacific Coast.

Looking back on the past history of the gem traffic, as we have thus sought to outline it, we may say, that since the dawn of history the principal markets for the gathering and distribution of precious stones have been probably the following: Ancient India, Egypt, Babylon, Tyre, Alexandria, Rome, Byzantium, Venice, Augsburg, Golconda, Goa, Colombo, Ratnapura, Amsterdam, Antwerp, Paris and London. For the semi-precious stones and agates, Oberstein, in Germany, St. Claude, in the French Jura, and the great fair at Nijni Novgorod, in Russia, are the most important; and the United States is the ultimate home of from one-third to one-half of the world's product.

[The lecture was profusely illustrated throughout with the aid of lantern slides.]

IN MEMORIAM.

MATHEW CAREY LEA.

Our late member, M. Carey Lea, was the son of the distinguished naturalist, Isaac Lea, LL.D., and Frances A. Lea. His maternal grandfather was Mathew Carey, widely known as a publisher and writer on political economy. He was born August 16, 1823, being the second son of a family of three sons and a daughter, the eldest son dying in infancy. His brother, Henry C. Lea, the well-known publisher and writer upon historical subjects, still survives him at the age of 72. The father, who died in 1886, had reached the great age of 94.

The subject of this sketch was not sent to school or to college, but was given a very careful and thorough education by the best teachers procurable, under whose care his strong intellectual powers and retentive memory enabled him to acquire a culture at once broad and thorough in languages, literature, and the natural and physical sciences. His father's

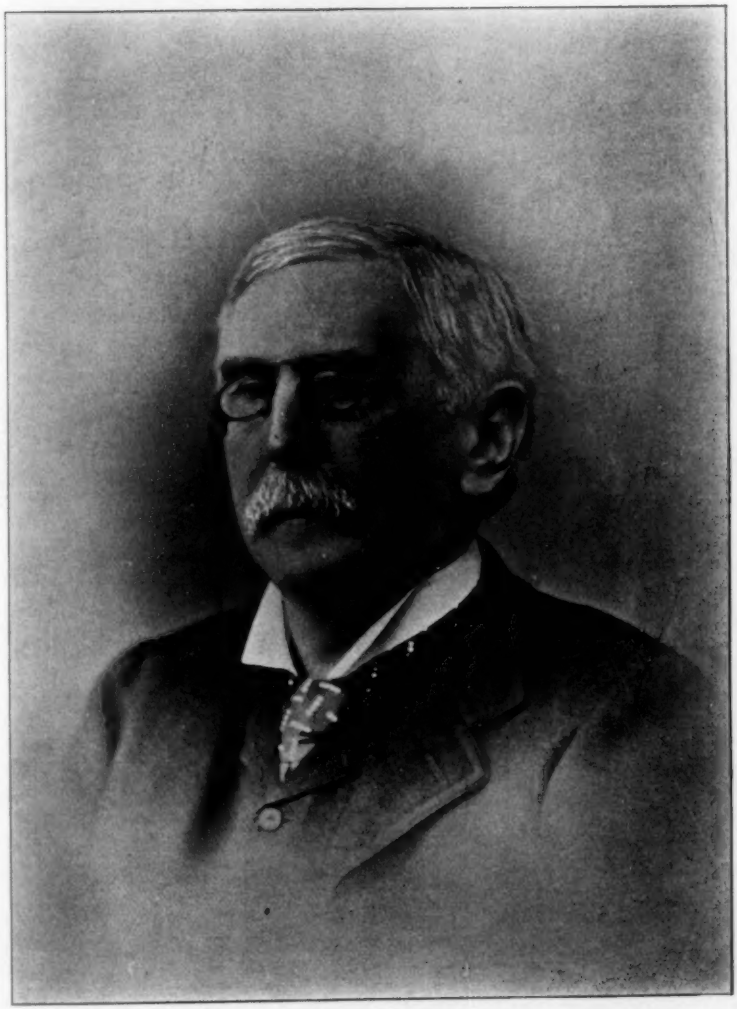
eminence as a student of natural history, coupled with the possession of ample means, furnished exceptional opportunities for him, even as a boy, to acquire this broad culture. Thus, in 1832, when 9 years of age, he accompanied his parents to Europe, where they spent over six months in travel and making the acquaintance of the most eminent English and Continental men of science, with many of whom his father had been in correspondence for years.

He was destined for the legal profession, and studied under the late Wm. M. Meredith, then the leader of the Philadelphia bar, and was admitted to practice about the year 1847. Ill health, not long after, forced him to abandon the profession, and he spent some years in Europe in search of relief, but from that time he remained more or less an invalid, with repeated attacks of illness, which incapacitated him for the active pursuits of life.

Shortly after abandoning the legal profession he entered the laboratory of Prof. Jas. C. Booth, and there acquired that love of chemical research to which he devoted the remainder of his life.

The branch of science which attracted him especially was the chemistry of photography. His contributions to this branch of science were numerous, and some of them of such capital importance that they secured for him a world-wide recognition as one of the half-dozen pioneer investigators who have laid the scientific foundations of photography.

From 1870 to 1878 he contributed to the photographic journals many papers of much practical value to amateur photographers on methods of preparing collodio-bromide emulsions and developing agents. Among his earlier contributions was the investigation of the influence of color on the reduction by light of the iodide, bromide and chloride of silver. Of more recent date were his experiments with a series of the salts of silver (chiefly the chlorides), with the view of making use of them in obtaining photographs of objects in their natural colors, summarized in a paper on the photo-chemistry of the silver haloids, which has been pronounced the most valuable contribution to photographic chemistry made in a quarter of a century.



M. CAREY LEA.
[1823-1897.]

He is best known to the chemical world by his description of the photo-bromide and photo-iodide of silver and the discovery of the identity of these salts with the substance of the latent photographic image, and by his remarkable discovery of the allotropic forms of silver. This extremely interesting and valuable discovery, which was published but a few years before his death, gained for him the honor of election to the National Academy of Sciences. He published, as early as 1868, his "Manual of Photography," a second edition of which appeared in 1871.

Along with these scientific studies he kept up his interest in literary culture, and his intimate acquaintance with the classics, and with what is best in the literature of Europe, of England, France, Germany, Italy and Spain, with all of the languages of which he was familiar.

Mr. Lea united himself with the Franklin Institute in 1848, and with the Chemical Section shortly after its organization. Although never participating actively in the work of the Institute, he manifested his appreciation of its rich possessions of scientific serials by availing himself frequently of the special privileges which the Library Committee was pleased to accord him, in recognition of his devotion to scientific research. The value which he placed upon the advantages thus derived from his connection with the Institute was manifested in his bequest to the Chemical Section of his large and valuable collection of physical and chemical apparatus and material and scientific books, and a fund to provide (in perpetuity) for the purchase of books and periodicals devoted to physics and chemistry.

He was twice married, first to Elizabeth Jaudon, widow of William Woodhouse Bakewell, of Cincinnati, who died in 1881, leaving a son, George H. Lea, and, secondly, to Eva Lovering, daughter of the late Prof. Joseph Lovering, of Harvard University. His son and widow survive him.

His death occurred at his residence at Chestnut Hill, Philadelphia, on the 15th of March, 1897.

S. P. SADTLER,
JNO. CARBUTT,
WM. H. WAHL.

APPENDIX.

LIST OF THE MORE IMPORTANT SCIENTIFIC PAPERS OF M. CAREY LEA.

Numerical Relations between Chemical Equivalents. *American Journal of Science*, vols. I and II, 1860.

Production of Ethylamine by Reactions of the Oxy-ethers. *American Journal of Science*, vol. II, 1860.

Sources of Error in the Detection of Potash. *American Journal of Science*, vol. I, 1861.

Production of Ethyl-bases. *American Journal of Science*, vol. II, 1861.

Exact Separation of Ethyl-Bases. *American Journal of Science*, vol. II, 1861.

Preparation of Ethyl Nitrate and Nitrite. *American Journal of Science*, vol. II, 1861.

Reactions of Ethylamine and Diethylamine. *American Journal of Science*, vol. I, 1862.

Production of Methyl-bases and Formation of Methyl Nitrate. *American Journal of Science*, vol. I, 1862.

On Methylamine. *American Journal of Science*, vol. I, 1862.

On Triethylamine. *American Journal of Science*, vol. II, 1862.

Arithmetical Relations of Chemical Equivalents. Influence of Ozone and other Chemical Agencies on Germination and Vegetation. *American Journal of Science*, vol. I, 1864.

Remarks on the Distillation of Substances of Different Volatilities. *American Journal of Science*, vol. I, 1864.

Notes on the Platinum Metals and their Separation from each Other. *American Journal of Science*, vol. II, 1864.

Notes on the Reactions of the Platinum Metals. *American Journal of Science*, vol. II, 1864.

Colored Derivatives of Naphthaline. *American Journal of Science*, vol. II, 1864.

Preparation of Oxalate of Ethyl. *American Journal of Science*, vol. I, 1865.

Reactions of Gelatine. *American Journal of Science*, vol. II, 1865.

Nature of the Invisible Photographic Image. *American Journal of Science*, vol. II, 1865.

Detection of Iodine. *American Journal of Science*, vol. II, 1866.

Nature of the Action of Light on Silver Iodide. *American Journal of Science*, vol. II, 1866.

New Manipulations. *American Journal of Science*, vol. II, 1866.

Influence of Organic and Inorganic Substances on Germination and Vegetation. *American Journal of Science*, vol. I, 1867.

Contributions toward a Theory of Photo-Chemistry. *American Journal of Science*, vol. II, 1867.

New Test for Hyposulphites. *American Journal of Science*, vol. II, 1867.

On Nitroglucose. *American Journal of Science*, vol. I, 1868.

Criticism on a Proposed Method of Estimating Ethylic Alcohol in Presence of Methylic. *American Journal of Science*, vol. I, 1872.

Influence of Color on Reduction by Light. *American Journal of Science*, vol. I, 1874.

Laboratory Notes. *American Journal of Science*, vol. I, 1874.

Nature of Action of Light on Silver Bromide. *American Journal of Science*, vol. I, 1874.

Detection of Hydrocyanic Acid. *American Journal of Science*, vol. I, 1875.

Action of the less Refrangible Rays on Silver Iodide and Bromide. *American Journal of Science*, vol. I, 1875.

Influence of Color on Reduction by Light. *American Journal of Science*, vol. I, 1875.

Explosive Properties of Methyl Nitrate. *American Journal of Science*, vol. II, 1875.

Notes on Sensitiveness of Silver Bromide to Green Rays as Modified by other Substances. *American Journal of Science*, vol. I, 1876.

Sensitiveness to Light of Various Salts of Silver. *American Journal of Science*, vol. I, 1877.

On Certain New and Powerful Means of Rendering Visible the Latent Photographic Image. *American Journal of Science*, vol. II, 1877.

Action of Certain Organic Substances in Increasing the Sensitiveness of the Silver Haloids. *American Journal of Science*, vol. II, 1877.

Reactions of Silver Chloride and Bromide. *American Journal of Science*, vol. I, 1878.

On Ammonio-argentic Iodide. *American Journal of Science*, vol. I, 1878.

On Combinations of Silver Chloride and Iodide with Coloring Matters. *American Journal of Science*, vol. I, 1885.

On Red and Purple Chloride, Bromide and Iodide of Silver. On Heliochromy and on the Latent Photographic Image. *American Journal of Science*, vol. I, 1887.

Identity of the Photosalts of Silver with the Material of the Latent Photographic Image. *American Journal of Science*, vol. I, 1887.

On Photo-bromide and Photo-iodide of Silver. *American Journal of Science*, vol. I, 1887.

Image Transference. *American Journal of Science*, vol. II, 1887.

Combinations of Silver Chloride with other Metallic Chlorides. *American Journal of Science*, vol. II, 1887.

On Allotropic Forms of Silver. *American Journal of Science*, vol. I, 1889.

On Allotropic Forms of Silver. *American Journal of Science*, vol. II, 1889.

On the Properties of Allotropic Silver. *American Journal of Science*, vol. II, 1889.

On Ring Systems and other Curve Systems produced on Allotropic Silver by Iodine. *American Journal of Science*, vol. II, 1889.

On Gold-colored Allotropic Silver. *American Journal of Science*, vol. I, 1890.

On Allotropic Silver. *American Journal of Science*, vol. I, 1891.

On Allotropic Silver. (Read before the National Academy of Sciences, April 24, 1801, by Prof. Ira Remsen).

On Allotropic Silver, Blue Silver, Soluble and Insoluble Forms. *American Journal of Science*, vol. I, 1891.

Notes on Allotropic Silver. *American Journal of Science*, vol. II, 1891.

Franklin Institute.

[*Proceedings of the annual meeting held Wednesday, January 19, 1898.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 19, 1898.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 163 members and visitors.

The annual report of the Board of Managers, the reports of the various Committees and Sections, and of the Trustees of the Elliott Cresson Medal Fund, were presented. They were accepted and ordered filed. (*See Appendix.*)

The Secretary presented letters of thanks to the Institute from the New England Cotton Manufacturers' Association and the Local Committee of Entertainment, for courtesies extended to members of the Association on the occasion of the meeting that body in Philadelphia, on October 27–28, 1897.

Dr. A. C. Crehore, of Hanover, N. H., and Lieut. Geo. O. Squier, U.S.A., presented a joint communication on the Synchronograph, a system invented by them for the rapid transmission of intelligence by the use of the alternating current. The communication embraced a description of the general principles of the system, and an account of the tests lately made, under the direction of Mr. W. H. Preece, Engineer-in-chief of the British Postal System, in operating the Wheatstone instruments by the alternating current, according to the synchronograph method devised by the authors.

Mr. Melvin L. Severy, of Boston, Mass., described and showed in practical operation, the Severy impression process. This is claimed to be an improvement upon the present method of printing, by the use of which an instantaneous and perfect adjustment of the printing surfaces is secured *automatically*, thus dispensing with the tedious and expensive operation known as "make-ready." (Referred to the Committee on Science and the Arts for investigation and report.)

Mr. H. H. Gross described and illustrated the construction and principle of operation of the so-called "Luxfer" prisms. This invention is designed to secure the more efficient diffusion of light in basements, vaults, and poorly-lighted apartments generally. (Referred to the Committee on Science and the Arts for investigation and report.)

The report of the tellers of the annual election was presented. The result of the election was as follows:

For *President*	(to serve one year), ...	JOHN BIRKINBINE.
" *Vice-President*	(" three years), ...	GEORGE V. CRESSON.
" *Secretary*	(" one year), ...	WM. H. WAHL.
" *Treasurer*	(" "), ...	SAMUEL SARTAIN.
" *Auditor*	(" three years), ...	JOHN GEORGE COPE.
" "	(for the unexpired term of J. H. Cooper, deceased), ...	WM. H. GREENE.

For *Managers* (to serve three years).

GEORGE H. FRAZIER,	ALEX. KRUMBHAAR,
ALFRED C. HARRISON,	C. HARTMAN KUHN,
HENRY R. HEVL,	SAMUEL M. VAUCLAIN,
HERBERT M. HOWE,	GEORGE VAUX, JR.

For the *Committee on Science and the Arts* (to serve three years).

L. L. CHENEY,	J. LOGAN FITTS,	LINO F. RONDINELLA,
JAMES CHRISTIE,	CHAS. A. HEXAMER,	A. J. ROWLAND,
LUIGI D'AURIA,	JACOB Y. MCCONNELL,	SAMUEL SARTAIN,
J. M. EMANUEL,	CLAYTON W. PIKE,	T. CARPENTER SMITH,
WM. PENN EVANS,	STACY REEVES,	THOMAS SPENCER.

The tellers received a vote of thanks for their services.

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held January 5, 1898.*]

MR. JAMES CHRISTIE in the chair.

Reports on the following subjects were considered:

Compound Locomotive Engine.—Clifton L. Reeves, Trenton, N. J. (First reading.)

Process and Apparatus for Manufacturing Carbureted Water-gas.—Henry C. Rew, Chicago, Ill. Discussed and referred back to sub-committee with additional members.

Wave Motors.—Henry Lotzgesell, Philadelphia. Referred back to sub-committee.

Steel-Lined Aluminum Culinary Ware.—Romain C. Cole, New York. Referred back to sub-committee.

Franklin Institute Grand Medal. Held under advisement.

Balanced Driving Wheel for Locomotives.—Philip Z. Davis, Philadelphia. Reconsidered on the applicant's request, to permit him to present new evidence of the utility of his invention.

[An abstract of this Committee's annual report is incorporated in the Annual Report of the Board of Managers, printed elsewhere in this impression of the *Journal.*] W.

SECTIONS.

CHEMICAL SECTION.—*Stated Meeting* held Tuesday, 18, 1898. President, Dr. Lee K. Frankel, in the chair.

Prof. W. C. Day presented a communication "On the Action of Carbon Dioxide on Sodium Aluminate and on the Formation of a Basic Aluminium Carbonate." Discussed by Dr. Keller, Prof. Bradbury and the author.

Prof. F. A. Genth, Jr., gave an oral account of an observation he had made in reference to the detection of salicylic acid in food products, which seemed to indicate that the accepted method was unreliable. The communication was announced to be a preliminary one, and further information on the subject was promised in the near future.

The following officers were elected for the year 1898, viz.:

President—Dr. Lee K. Frankel.

Vice-Presidents—Dr. Bruno Terne and Dr. W. J. Williams.

Secretary—Mr. Lyman F. Kebler.

Conservator—Dr. Wm. H. Wahl.

The accompanying Annual Report of the Section was approved, and ordered to be transmitted to the Institute:

JANUARY 1, 1898.

TO THE COMMITTEE ON SECTIONAL ARRANGEMENTS.

Gentlemen:

I am directed to submit the following report of the operations of the Chemical Section, during the year 1897.

The officers of the Section were:

President—Dr. Joseph W. Richards.

Vice-Presidents—Dr. Bruno Terne and Dr. Lee K. Frankel.

Secretary—Mr. Lyman F. Kebler.

Conservator—Dr. Wm. H. Wahl.

The Section has held stated monthly meetings as required by the by-laws of the Institute, on the third Tuesday of each month (except in July and August).

A list of communications presented and discussed is hereto appended. In addition to these, four evenings were devoted to lectures on subjects germane to the objects of the Section. These are also listed. A number of these contributions have appeared in the *Journal*.

The membership of the Section at the close of 1896 was 106. During the year 1897 there were added to the roll six new members. The losses of membership during the year were seven, leaving a net membership at the close of 1897, of 105, a decrease of 1.

A circumstance of much importance, as affecting the prosperity of the Section, was reported during the year 1897, viz., the bequest to the Section, by its deceased member, Mr. M. Carey Lea, of his scientific library and apparatus, and of the income of a piece of real estate, to provide a permanent fund for the purchase of books and periodicals devoted to chemistry and physics.

The books and physical and chemical apparatus received from this bequest represent a value of several thousand dollars, and, as soon as the needful facili-

ties can be furnished, the latter will be made available to the members, under proper restrictions. The income of the book fund, it is expected, will become available during 1898, and will probably amount to about $150 yearly.

Following is a list of the lectures and communications presented to the Section during the past year:

LECTURES.

Feb. 16th, Wiley (Dr. H. W.). "Soil Microbes Useful in Agriculture."

April 20th, Leffmann (Dr. Henry). "The Chemistry of Food Adulteration."

June 15th, Richards (Dr. Jos. W.). "A Critical Review of Methods of Determining Minerals."

Nov. 16th, Terne (Dr. Bruno). "Ammonia and its Sources."

COMMUNICATIONS.

Jan. 19th, Nitze (H. C. B.). "Recent Developments in the Magnetic Treatment of Ores, Describing the Wetherill Magnetic Concentrator."

Jan. 19th, Richards (Dr. Jos. W.) and Thomson (J. A.). "Recent Determinations of the Electric Conductivity of Aluminium."

Jan. 19th, Kebler (Lyman F.). "Volumetric Estimation of Acetone."

Jan. 19th, Richards (Dr. Jos. W.). "A New Laboratory Grinder."

March 16th, Leonard (C. L.). "The Permeability of Different Qualities of Aluminium to the Roentgen Rays."

March 16th, Richards (Dr. Jos W.). "The Relation Between the Latent Heat of Fusion of the Elements and their Melting Points."

May 18th, Shapleigh (Waldron). "Notes on Lucium."

May 18th, DuBois (H. W.) and Mixer (C. T.). "On the Determination of Insoluble Phosphorus in Iron Ores."

May 18th, Keller (Dr. H. F.) and Maas (Philip). "Some New Derivatives of Diacetyl."

Sept. 21st, Sadtler (Prof. S. P.). "Formation of Petroleum from Linseed Oil."

Sept. 21st, Sadtler (Prof. S. P.). "Remarks on Peanut Oil."

Oct. 19th, Keller (Dr. H. F.). "Analysis of Electrolytic Copper."

Oct. 19th, Maas (Philip) and Keller (Dr. H. F.). "Vanadium Minerals from Leadville, Col."

Dec. 21st, Peckham (S. F.). "Chemistry of the California Petroleums."

Respectfully submitted by order of the Section.

LYMAN F. KEBLER, *Secretary.*

ELECTRICAL SECTION.—*Stated Meeting* held Tuesday, January 11, 1898. President, W. E. Harrington in the chair.

Mr. David Pepper, Jr., read a paper on "Line and Return-Circuit Construction of Electric Railways." (Referred for publication.)

ANNUAL REPORT:

PHILADELPHIA, January 16, 1898.

TO THE COMMITTEE ON SECTIONAL ARRANGEMENTS.

Gentlemen:

I beg to submit a report of the work of the Electrical Section during the year 1897.

The following papers were presented :

Jan. C. J. Reed—New Induction Telegraph Apparatus.
Wm. C. L. Eglin—"Some Tests on Enclosed Arc Lamps."
Feb. Wm. H. Weston—"Sub-division of Rheostat Coils."
Mar. C. J. Toering—"Enclosed Arc Lamps."
April. H. L. Sayen—"New Form of Crookes Tube with Automatically Adjustable Vacuum."
May. Jos. Sachs—"Electric Elevators."
E. G. Willyoung—"Circuit Breakers for Induction Coils."
Oct. C. E. Carpenter—"Electric Current Controlling Devices."
Prof. W. D. Marks—"Electric Meters."
Nov. J. L. Woodbridge—"The Booster System applied to Electric Railways."
W. E. Harrington—"Railway Bonding."
Dec. Mark A. Replogle—"Speed Government in Water Powers."
Paul A. Winand—"The Constant Current Transmission of Power."

The increase in membership during the year has been gratifying, while the loss of old members by resignation or otherwise has been trifling.

A considerable increase in the average attendance, which has been during the year about sixty, is an even better guarantee of the interest in the work of the Section.

Respectfully yours,

CLAYTON W. PIKE, *President.*

MINING AND METALLURGICAL SECTION.—*Stated Meeting* held Wednesday, January 12, 1898. President, Benj. S. Lyman, in the chair.

Mr. Pedro G. Salom read a paper on "The Electrolytic Production of Lead from Galena." The method is based on the reduction of lead directly from the sulphide ore, in an electrolyte of aqueous sulphuric acid through the agency of hydrogen. The paper was discussed by Mr. C. J. Reed and the author. The author submitted specimens of lead sponge and various oxides of lead obtained in his process. (Referred for publication.)

Mr. Benj. S. Lyman presented a communication entitled : "Some Illustrations of the Influence of Geological Structure on Topography." (Referred for publication.)

The following officers were elected for the year 1898, viz. :

President—Mr. A. E. Outerbridge, Jr.

Vice-Presidents—Dr. David K. Tuttle and Mr. James Christie.

Secretary—Mr. Wm. C. Henderson.

Conservator—Dr. Wm. H. Wahl.

The accompanying annual report of the Section was approved and ordered to be transmitted to the Institute. viz. :

TO THE COMMITTEE ON SECTIONAL ARRANGEMENTS.

Gentlemen :

In presenting this first annual report of the Mining and Metallurgical Section of the Franklin Institute, it has been thought of possible interest to enter upon a resumé of the events that have led to establishing this Section.

The Mining and Metallurgical Section is the outgrowth of the Committee on Minerals and Geological Specimens; it owes its existence to the untiring efforts of Mr. Benj. Smith Lyman, chairman of that committee, who, in a letter to Mr. John Birkinbine, President of the Institute, dated February 20, 1897, brought the matter up in the following terms:

"Before any final decision of the fate of our Committee on Minerals and Geological Specimens, it may be worth while to consider an idea or two that have occurred to me * * * It has long seemed quite possible that so large a number of men, members of the American Institute of Mining Engineers, interested in mining and metallurgy, and inclined to associate themselves with others, might find it agreeable, useful and convenient to meet for paper reading and discussion, and social intercourse, more frequently than the half yearly, generally distant meetings of the Institute * * * A close association and frequent meeting of mining engineers and metallurgists, under the Franklin Institute, would cost them no additional annual fee (unless they chose to increase the attraction by a small subscription for some slight refreshment); they would have the pleasure, instruction and manifold profit of a society; and perhaps could publish some of their valuable results in the FRANKLIN INSTITUTE JOURNAL. * * * The proposed Association of Mining Engineers and Metallurgists in the Franklin Institute might either be organized as a Mining Section, or a Mining and Metallurgical Section."

At the meeting of the Committee on Minerals and Geological Specimens, held March 10, 1897, Mr. Lyman laid the matter of the organization of a Mining and Metallurgical Section before the committee, and it was finally decided to issue to such persons as it was thought would be interested, the circular letter which bears the date of March 31, 1897, the purpose of the letter may be gathered from the following extract:

DEAR SIR:—The Standing Committee on Minerals and Geological Specimens of the Franklin Institute has done nothing for many years past, as the specimens have been deposited with the Academy of Natural Sciences, but now desires to become active again, with perhaps some modification of scope or of organization, and requests your co-operation in forming an important Mining and Metallurgical Museum, and a Mining and Metallurgical Section of the Institute. * * * You are invited to signify your approval of the plan by signing the enclosed card and returning it to the Franklin Institute, so that, if there be reasonable encouragement, a meeting may be shortly called to organize the Section.

By order of the Committee on Minerals and Geological Specimens.

BENJ. SMITH LYMAN,
Chairman.

This letter evoked a favorable response from sixty-two persons. Upon this encouragement a meeting was called for the evening of April 28, 1897. This inaugural meeting was attended by thirty-five persons, the Section was organized, and at the adjourned meeting, held May 12, 1897, the following officers were elected to serve during the year:

President—Mr. Benj. Smith Lyman.
Vice-Presidents—Dr. D. K. Tuttle, Mr. A. E. Outerbridge, Jr.
Secretary—Mr. Wm. C. Henderson.
Conservator—Dr. Wm. H. Wahl.

Six meetings have been held during the year, with an average attendance of thirty. There have been read before the Section eleven papers, as follows:

(1) "Mechanical and Engineering Progress as Influenced by the Mining Industry," John Birkinbine.

(2) "The Undeveloped Mineral Wealth of Newfoundland," A. E. Outerbridge, Jr.

(3) "Compass Variation as Affected by Geological Structure in Bucks and Montgomery Counties, Pa.," B. S. Lyman.

(4) "Underground Water Supply," F. L. Garrison.

(5) "Monazite," H. B. C. Nitze.

(6) "A Special Process for Treating Cast Iron," Charles James.

(7) "Some Remarks on Wire-Glass," Francis Schumann.

(8) "Copper Traces in Bucks and Montgomery Counties, Pa., B. S. Lyman.

(9) "Forestry as Related to Geology and Engineering," John Gifford.

(10) "Kryolith: its Mining, Preparation and Utilization," Wm. C. Henderson.

(11) "Fatigue of Metals in Iron and Steel Forgings," H. F. J. Porter.

The membership to date consists of seventy-three persons.

Quite a number of interesting communications have been promised for the near future, among which may be mentioned:

(1) "The Electrolytic Production of Lead from Galena," Pedro D. Salom.

(2) "The Practical Aspect of Present Methods of Testing Iron and Steel," Paul Kreuzpointner.

(3) Building Stones," Alexis A. Julien, Ph.D.

(4) "The Development of the American Portland Cement Industry," Robert W. Lesley.

(5) "The Secret of the Strait," Lewis M. Haupt, C.E.

(6) "Gold Mining in Georgia," William Tatham.

(7) "Japanese Swords," Capt. E. L. Zalinski.

(8) "The Supply of Iron Ore," John Birkinbine.

At present the outlook for the Section's future seems very encouraging, and it is believed by those most interested in its welfare that the Mining and Metallurgical Section has fairly entered upon a field of great usefulness and prosperity.

By direction of the Mining and Metallurgical Section.

WM. C. HENDERSON,
Secretary.

ANNUAL REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE.

(For the year 1897.)

The Board of Managers of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts respectfully presents the following report of the operations of the Institute for the year 1897:

MEMBERS.

Members at the close of 1896	1,867	
Number of new members elected who have paid their dues in 1897	100	
		1,967
Lost by death, resignation and non-payment of dues,		129
Total membership at the end of 1897		1,838

LIBRARY.

The additions to the Library during the past year numbered nearly 3,000 new titles, a gratifying exhibit in view of the diminished income of the Committee. This good showing was made possible through the accession, by bequest, of the valuable private library of the late M. Carey Lea. The storing of the library in the new fire-proof stack-room, now almost ready for their reception, will insure the safety of these invaluable literary treasures, and will be a cause for satisfaction to the members of the Institute. It may not be amiss to note the fact that, exclusive of a considerable number (about 5,000) of maps, charts, etc., the library of the Institute at present contains the imposing number of 80,000 books and pamphlets. As a large proportion of this collection is composed of serial publications used for study and reference, and as many of the books are long out of print and difficult of replacement if lost or destroyed, the course adopted by the managers, in making provision for the better security of the library, it is believed, will be cordially approved by the members.

JOURNAL.

The financial statement of the *Journal* for the year 1897 (see appendix) exhibits a slight improvement in the receipts, over those for the previous year, although this increase is not as large as was anticipated when the year began. The Committee on Publications reports that the prospect for the present year is encouraging, and affords reasonable basis for the hope that the next accounting will exhibit a surplus.

The service rendered to the library by the exchanges of the *Journal*, though it does not appear in its cash account, is invaluable, and represents annually the addition of about $1500 worth of the most valuable class of current scientific and technical literature.

The Board desires to express its high appreciation of the services rendered to the Institute by the editorial branch, and of the care and economy with which the business affairs of the *Journal* have been conducted by the Committee on Publications.

COMMITTEE ON SCIENCE AND THE ARTS.

This Committee has exhibited its customary activity during the past year. The cases received for investigation, or referred to the Committee by the Institute, numbe ed 46. The number of cases reported upon, or otherwise disposed of, was 52. There have been awarded or recommended, through this Committee's agency, of Elliott-Cresson Medals, 4; of John Scott Premiums and Medals, 11; of Edward Longstreth Medals, 5, and of Certificates of Merit, 1. In 20 cases no awards were made.

OTHER COMMITTEES.

During the past year, the attempt was made to revivify several of the standing committees, whose work for many years had been allowed to fall into abeyance.

The Committee on the Cabinet of Arts and Manufactures has held several meetings during the year. It reports that while a Cabinet of Arts and Manufactures does not at present exist, and while there are grave doubts as to the advisability of undertaking to establish one, it is possible that in the clearing and rearranging of the building, incident to the removal of the books to the new stack, or at an exhibition that may be held in the near future, there may be found material which it will be the province of this committee to arrange and care for.

The Committee on the Cabinet of Minerals and Geological Specimens likewise has held several meetings at which, the question of its present and future operations was considered. It was ascertained that the small collection at one time in possession of the Institute had been deposited—some fifteen years ago—with the Academy of Natural Sciences, for the reason that the room in which it had been displayed was needed for the Drawing School.

The Committee considered that the general purposes for which it had originally been instituted could be much better subserved by a Section of Mining and Metallurgy to be devoted to the promotion of these and kindred branches of applied science, for the formation and maintenance of which the present by-laws of the Institute make liberal provisions.

The outcome of the Committee's discussion of these matters was the formation of a Section on the lines above indicated, which was authorized by the Board at its stated meeting of April 14, 1897. This Section has at present a membership of 73, and has fully justified the hopes of its founders as to its utility.

The Committee concludes its annual report with the statement that this Section meets the present needs and opportunities in its special field so fully that there no longer exists any substantial reason for the Committee's continuance, and recommends accordingly that it be discontinued.

The Committee on Meteorology met several times during the year for the reading and discussion of professional papers, and also for the consideration of the question of its future work. With reference to this, the following statements are contained in the Committee's annual report.

"Respecting the future of the Committee, there is room for differences of opinion, but since the diversion of the work of the State Weather Service from the control of the Institute, several years ago, there appears to be nothing in sight with which the Committee could actively employ its members,

with direct advantage to the Institute, that could not be much better and much more effectively undertaken through the instrumentality of a Section devoted to Meteorology and Climatology.

"The liberal provisions of the By-laws of the Institute afford an easy method by which all members who are interested in this branch of science may become associated, for the purpose of pursuing it with greater possible benefit to themselves and to the Institute, than through the instrumentality of a committee restricted in membership to ten persons.

"The Committee on Meteorology, therefore, would respectfully suggest that it be discontinued, and that an effort be made to create in its stead a Section of Meteorology and Climatology."

The Committee on Meetings has held regular sessions during the year, the results of which have appeared in the programs of the stated meetings of the Institute, printed in the *Bulletin* issued monthly under the Committee's direction, and sent to all members in good standing.

At the ten stated meetings of the Institute, seventeen papers and other communications were presented, some of which were of considerable importance. This is especially true of the "Smoke Prevention" question, referred to the Institute by the Bureau of Health, of Philadelphia, which called forth an extended discussion, and which included the presentation of descriptions of all the important forms of improved furnaces and automatic stokers in use throughout the country. The conclusions reached by the Institute, as the result of the careful consideration which the subject received, will shortly be officially laid before the Bureau of Health, and, it is believed, will prove of substantial service in the framing of legislation on the subject, which is now admitted to be necessary.

The Committee on the Cabinet of Models has held several meetings, at which it was decided to make a complete examination of all the models in possession of the Institute with the view of making a judicious selection of the same, reserving for classification, cataloguing and preservation those which appear to have sufficient value, and discarding such as seem to be valueless. The Committee had made considerable progress with this work, when its members were compelled to suspend the work on account of the building alterations decided on by the Board. The Committee intends to resume and complete its work as soon as opportunity is afforded.

LECTURES.

The Committee on Instruction, with the co-operation of the professors, succeeded during the past year in arranging a more miscellaneous and generally useful series of lectures than heretofore.

In view of the difficulty heretofore experienced in attracting large audiences to the lecture-room of the Institute to listen to lectures of a technical character, it was decided to assign all such to one or another of the Sections, in the form of communications for reading and discussion. This course has proved satisfactory, not only by increasing the activity and importance of the Sections, but also by affording the contributors of technical papers a select and more appreciative audience of experts.

In furtherance of this general scheme, arrangements were made with the officers of Central Branch of the Young Men's Christian Association, for

giving six of the most attractively illustrated lectures, in the more commodious and centrally-located hall of the Association, at Fifteenth and Chestnut Streets, without charge for rental, and with the sole condition that they were to be announced as given under the joint patronage of the two societies.

Thus far the experiment has proved highly satisfactory. The attendance has been large, and the members of the Institute have very generally availed themselves of the opportunity of profiting by the arrangement.

The Board calls attention to the fact that, as in previous years, its Committee on Instruction has been able to obtain the services of its lecturers (many of whom are men of distinguished reputation) without remuneration, the sincerest evidence that could be presented of the respect in which the Institute is held. The Board recommends that the Institute should testify its appreciation of the gratuitous services of its lecturers by the passage of a vote of thanks.

DRAWING SCHOOL.

The attendance of pupils in the Drawing School, and in its Branch School at Germantown Junction, shows a slight increase over the previous year, encouraging the hope that the steady diminution in the number of pupils that we have had to note for the past three or four years, has at length been arrested.

The efficiency of the Schools has been fully maintained.

The expediency of establishing, in connection therewith, classes for instruction in mathematics is under consideration.

SECTIONS.

The Chemical and Electrical Sections exhibited during the past year a commendable degree of activity, and the character of the professional papers read and discussed at the meetings (many of which have enriched the pages of the *Journal*) amply demonstrated the utility of affording the members the fullest opportunity to form such associations within the Institute for mutual improvement and as a stimulus for the advancement of the Arts and Sciences.

The Institute has been strengthened during the past year by the formation of a new Section devoted to Mining, Metallurgy and kindred branches of applied science. This Section has already a large membership, and, from the interest taken in its meetings, gives promise of an active and useful career.

The programs of the Electrical and Mining and Metallurgical Sections, as will appear from an inspection of the list of papers printed in the announcement book, have been so well filled as to have made it necessary, in a number of instances, to increase the number of meetings to two in each month.

GENERAL REMARKS.

Summarizing the results of the work of the past year, it may fairly be stated that every branch of the Institute has made the best possible use of its opportunities for active work. The serious limitations which lack of funds and lack of space have imposed upon the Committees and the Sections are too well known to need repetition.

The present improving condition of general business encourages the hope that the Endowment Committee, lately established by your Board, may be successful in its efforts to secure a substantial sum by subscription to provide a maintenance fund, out of the income of which the current work of the Institute may be conducted on a scale of proper efficiency.

The alterations in the building, now approaching completion, were determined upon by your Board after the most careful consideration. When completed, it is believed that the greater safety to the library which will be secured thereby, and the large amount of room for reading tables, the display of interesting models and other uses, that will be gained by the change will be found most satisfactory, and that the advantages the members will derive therefrom will amply justify the Board's action.

The Institute's financial statement for the year 1897 is hereto appended.

By order of the Board,

JOHN BIRKINBINE, *President.*

HALL OF THE INSTITUTE, PHILADELPHIA, January 12, 1898.

APPENDIX.

FINANCIAL STATEMENT FOR THE YEAR 1897.

Balance on hand, January 1, 1897		$196 99
Receipts:		
*Committee on Publications	$2,802 78	
Committee on Library	26 30	
Committee on Instruction	807 00	
Committee on Science and the Arts	151 20	
Committee on Meetings	16 50	
Curators	11 50	
Committee on Stocks and Finance	633 33	
Income Bloomfield H. Moore Memorial Fund	785 90	
Income Memorial Library Fund	55 45	
Frederick Graff Fund	3 00	
Interest on Investments of funds in the hands of the Board of Managers	940 00	
Income from Endowments in the hands of the Board of Trustees	2,023 25	
Receipts from Members, annual	5,780 25	
Receipts from Life Memberships	392 00	
Entrance Fees Non-Resident Members	145 00	
Interest on bank deposits	14 87	
Receipts from sales of Index to *Journal*	35 00	
Receipts from sales of Exhibition Reports	12 65	
Receipts from sales of Membership Certificates	5 00	
Electrical Section (a donation to)	31 00	
Temporary Loan	2,000 00	
Scott Legacy Premiums	200 00	
Proceeds of Sales of Central Railroad of New Jersey Bonds	2,200 70	
Interest on B. H. Bartol Fund	50 00	
		$19,122 68
		$19,319 67
Payments:		
Committee on Publications	$4,657 32	
Committee on Library	1,071 08	

* Credits other than cash to the account of Committee on Publications representing the value of exchanges, books reviewed and books purchased in exchange for advertising space, aggregated $1,504 70.

Bloomfield Moore Fund Expenditures	519 44	
Memorial Library Fund Expenditures	45 42	
Committee on Instruction	1,041 86	
Committee on Meetings	334 71	
Committee on Science and the Arts	195 04	
Curators	1,621 01	
Incidental Expenses	669 56	
Salaries and Wages	4,626 50	
Chemical Section	117 62	
Electrical Section	111 00	
Mining and Metallurgical Section	56 28	
Committee on Exhibitions	50 00	
Interest on Temporary Loans	395 17	
Insurances	531 89	
Committee on Building Alterations	2,395 81	
Actuary's Petty Cash Fund (to be accounted for)	200 00	
Contributions for Life Membership (paid to Board of Trustees)	400 00	
Certificates of Membership	2 00	
Scott Legacy Premium	200 00	
		$19,239 71
Balance		$79 96

ENDOWMENT FUNDS.

The Permanent Endowment Funds of the Institute, at the end of 1897, consist of the following:

(In the hands of the Institute.)		
Bloomfield H. Moore Memorial Fund	$15,000 00	
Memorial Library Fund	1,000 00	
B. H. Bartol Fund	1,000 00	
Amount received from Life Memberships between January 1, 1891, and October 1, 1894	1,755 00	
		$18,755 00
(In the hands of Elliott-Cresson Trustees.)		
The Elliott-Cresson Medal Fund		4,667 68
(In the hands of the Board of Trustees of the Franklin Institute.)		
The legacy of George S. Pepper	$35,687 50	
The legacy of Eugene Nugent	1,000 00	
Legacy of Mrs. Emeline B. Nicholson	1,520 00	
The Edward Longstreth Medal Fund	1,000 00	
The donation of an unknown friend	5 00	
The donation of Sigmund Riefler	20 00	
Life membership fund since October 1, 1894	1,050 00	
Journal Endowment Fund	138 00	
By will of John Turner, deceased, one-fourth of net income on 2 per cent. of his residuary estate, yielding about $100 or more per year, equivalent to a capital sum of	2,000 00	41,520 50
Total		$64,943 18

[An increase in 1897 of $1920.]